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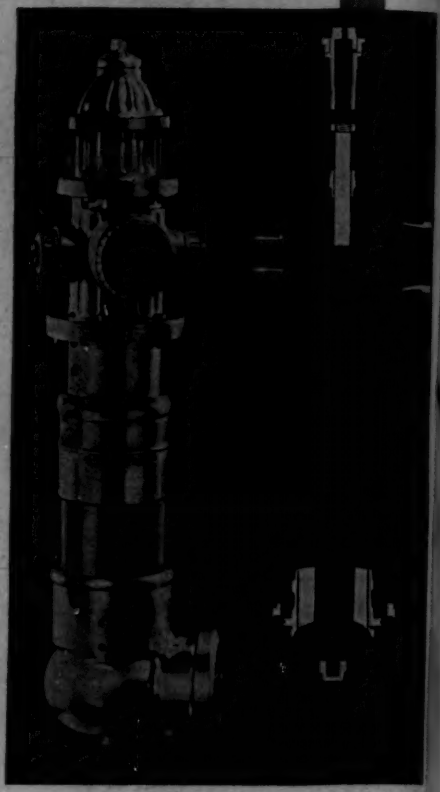

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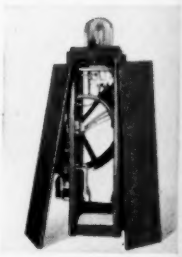

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Vol. 31 July, 1939 No. 7

Recovering from the Recovery Program

By Carl H. Chatters

THE topic assigned to me implies the superhuman task of appraising the results of the recovery program in the United States. The necessity for making constructive suggestions is also implied. Without prejudice or malice I have tried to see what is good, what is desirable but impractical, and what positively undersirable trends exist. Political and social action have brought tides of change that would not recede if every employable man returned to work tomorrow. Recovery therefore must be considered within the framework of the kind of society we have. While the United States seeks business recovery, it must recognize the necessity of preserving our political democracy. Short-sighted concessions for relief and recovery may mean the surrender of political rights for short-lived business safety.

Just what does recovery mean: To the laborer it means an opportunity to work at a decent wage and to change his place and type of occupation. The middle class man wants the assurance of work, the comforts of life, and the chance to save for old age. The business man interprets recovery to mean a certainty of profits, no impairment of his capital, control over his labor supply, a constantly in-

A paper presented on June 13, 1939, at the Atlantic City Convention by Carl H. Chatters, Executive Director, Municipal Finance Officers' Assn. of U. S. and Canada, Chicago.

creasing volume of business, and the freedom to conduct his enterprise as he wishes without regard to government or labor. Most readers of this paper have not really suffered. To such readers recovery means jobs for the unemployed, steady employment for themselves, less talk of taxes, less feeling that government seems to dominate their lives, and a sense of economic security.

It seems perfectly clear that recovery will never come if "recovery" means a return to the political, social or economic conditions prevailing before 1929, or 1900 or 1850. The world has moved too far and too fast. Therefore the first essential to recovery is a recognition by business leaders that times have changed and that they must seek means of accommodating themselves to the new era.

Guarantee of Individual Rights Needed

Recovery in a narrow material sense is relatively unimportant at the moment. What you and I would like is a guarantee of the right of the individual man, the individual business and the individual city to govern his or its own affairs. What we want is a guarantee of some consistent government policy. What we want most is a clear vision of the point toward which our leadership or lack of leadership is taking us. What industry really wants is a feeling that the present business autocracy and the existing political democracy will both survive.

This discloses the second essential to recovery: An understanding that *group relationships* have superseded *individual relationships* for the present, at least. The organized farmer deals with Congress through several major farm organizations. Industry and labor negotiate through representatives of groups spread over wide geographic or occupational areas. The professions, bulwarks of individualism, defend the right of the individual professional man, but the leading professional associations are themselves almost guild-like closed corporations. How refreshing it is, then, to see an outstanding man who dares still be himself and stand alone for what is right!

Business units have become large. At the same time organized government, particularly the federal government, has become more centralized. Labor has become class conscious and organized. We have gone much farther than we think. In this new economy the individual worker can seldom control his own destiny. The smaller units of government, the city, the county, or even the state have

much less influence over the lives of men. All these changes have important economic and political implications.

A political democracy seems possible only when it is composed of a large number of strong local units of government. In these units, government is close to the citizen and responsive to his wishes. But business is highly organized and centralized. A single corporation may do business in many states and many nations. This breeds tax conflicts between states and localities. The small unit of government finds itself impotent to deal with the large industrial unit. A government as highly centralized as industry, would soon become bureaucratic, tyrannical and unresponsive. For preservation of political democracy it is therefore necessary for industry to seek the means of existence within a decentralized government. Recovery, or even existence, requires a settlement of the conflicts between the federal, state and local governments; between big business and small business; between capital and labor; and between all sizes of business and all units of government.

Statistics on the Recovery Program

There is no use in being critical without knowing what you complain of and what you want in place of what you now have. To discuss properly the topic assigned, you must first get clearly in mind what conditions now seem wrong, the state of affairs to which you wish to arrive, and the means you would employ to get there. No political party brought the country to the business collapse of 1929. Our industrial and economic system committed suicide. No political party will be solely responsible for recovery, if it comes, nor for uncertainty if it remains. The leadership which you provide and the leaders the masses choose to follow will decide whether we continue as a political democracy or become a completely socialized state.

Let us now consider some of the events and conditions that have accompanied what some may have chosen to call the attempt at recovery. In seven years (February 2, 1932 to February 1, 1939) the Reconstruction Finance Corporation disbursed $7,243,873,197. Repayments have been made so that only $1,871,308,168 is outstanding. These billions were used: for benefits to agriculture; for opening 5,816 banks; for paying depositors in 2,773 closed banks; for bank capital; for self liquidating projects; for aiding business enterprises; for scaling the debts of drainage, levee and irrigation districts; for 82 railroads; for mortgage loan companies; for loans to

insurance companies and to building and loan associations; and for a few other minor purposes. The R.F.C. advances still outstanding are due substantially from the loans for bank capital, self liquidating projects, business enterprises, railroads, and mortgage companies. Ultimate losses will be only a small fraction of the original loans. Which of these loans do you consider opposed to recovery?

Other spending for the recovery program came from the Emergency Relief Appropriation Acts of 1935, 1936, 1937 and 1938. From April 18, 1935 to April 30, 1939 there was actually disbursed from the relief appropriations $10,498,757,136. Because you are interested in public utilities you may want to observe that $670,232,900 was spent on electrical utilities, water and sewage systems and other utilities. About $150,000,000 was spent for water purification and supply. Where did the $10½ billions spent for emergency relief go? Approximately one billion has been spent by the Bureau of Public Roads and the Farm Security Administration, another billion by the combined executive departments, Agriculture, Commerce, Interior, Justice, Labor, Navy, State, Treasury and War. The Works Progress Administration (and its N.Y.A. subsidiary) spent $6,582,265,526; the Federal Emergency Relief Administration, $934,168,242; the Civilian Conservation Corps, $592,554,708; and the Public Works Administration, $379,289,498. Fourteen other independent establishments have spent from $100,000 to $20,000,000 each. The story comes closer to home when you learn that there was spent in New Jersey alone, from the federal emergency relief appropriations $338,244,441. In a political democracy you still have the right to ask what was done with the ten and a half billions and what it accomplished.

The efforts to bring recovery through spending, and the expenditures for relief of unemployment have been accompanied also by an attempt to alter many relationships between business groups, and between labor and industry. Had there been far-sighted business policies, many of these difficulties might have been foreseen and adjusted. But instead there emerged the N.R.A., the S.E.C., and the National Labor Relations Board. Other regulatory commissions were established or invigorated. Large social groups have been selected for special attention through government aid: World War veterans, dependent children, the blind, the aged, the industrial castoff and the unemployed. Special legislation has been passed to assist the cotton farmer, the corn farmer, the hog raiser, the wheat

grower, the mortgagor, the mortgagee, the dweller in slums, and persons suffering from droughts and from floods.

Financial programs have been changing our political structure. The "bait" offered by the federal government practically forces each state to adopt particular social welfare programs or become ineligible for government grants. The federal government, controlling the relief purse, tells the states and local governments how much they may have for relief and what they must do to get it. Municipalities and counties, hurdling their state governments, appeal directly to the federal government for aid. The educational interests ask for vast federal grants for local schools hoping that no strings will be attached. Many states have received from the emergency relief appropriations alone more money than the state itself raised for all state purposes. If the tide of centralization cannot be turned, then bulwarks should be erected to prevent its further onrushes.

Business appears to voice three major criticisms of the recovery program: that the financing of relief, social security and business reform has brought heavier taxation; that part of the new taxes or new debts has been used to socialize industry; and that the relations between labor and industry have been changed by government support of labor.

Next we will examine certain indexes regarding the economic aspects of the recovery program. Income payments for wages and salaries, for other labor income and relief, for entrepreneurial withdrawals, and for dividends, interest, net rent and royalties are one valuable index. The income payments totalled as follows:[1] 1929, $79,988 million; 1933, 45,782 million; 1937, 70,645 million; and 1938, 64,000 million. The national debt has increased. In 1919 the peak war debt was $25,482,034,000 which declined in 1930 to a low point of $16,185,308,000. At the present time the national debt is $40,277,622,000 (as of May 25,1939).

The American Federation of Labor makes estimates of gainful workers and the number of unemployed. The latter include persons on relief projects. The relationships between the numbers unemployed, the volume of industrial production, and current price levels reveal the failure of the recovery program to eliminate unemployment or to establish parity between urban and rural purchasing power or

[1] Source: Nathan and Martin, *State Income Payments*, 1929-37, U. S. Bureau of Foreign and Domestic Commerce, May, 1939.

between the prices of manufactured goods and the prices of farm products (see tables 1 and 2).

The relief and recovery programs of the federal government have kept people from starving or rioting. But the attempts at recovery have not remedied unemployment. The balance between agriculture, industry and labor has not been attained or even approached. Far too many contradictions and inconsistencies in the program appear to nullify each other. The United States is like a sick patient who has been kept alive by artificial stimulants and a series of "shots in the arm." But the country, like the individual, cannot live forever

TABLE 1

*American Federation of Labor Unemployment Estimates**

YEARLY AVERAGES	GAINFUL WORKERS	NUMBER EMPLOYED	NUMBER UNEMPLOYED
1929	48,056,000	46,192,000	1,864,000
1930	48,752,000	43,982,000	4,770,000
1931	49,417,000	40,679,000	8,738,000
1932	50,060,000	36,878,000	13,182,000
1933	50,682,000	36,959,000	13,723,000
1934	51,288,000	38,924,000	12,364,000
1935	51,191,283	40,539,049	10,652,234
1936	51,758,980	42,364,426	9,394,553
1937	52,283,038	44,024,851	8,281,962
1938	52,879,211	41,942,945	10,936,265
MONTHLY FIGURES			
January, 1929	47,733,040	44,673,084	3,059,956
February, 1939	53,239,999	41,769,737	11,470,262

* From "The American Federationist," January, 1936 and April, 1939.

this way but must be brought back to normal living. On the other side many of the broad objectives of the new legislation are desirable but need to be refined from an administrative standpoint.

Without federal aid for unemployment relief, many local communities would have experienced rioting, bloodshed and extreme suffering in 1932 and the subsequent years. The majority of the states lacked constitutional power to borrow and statutory authority to increase revenues. The regions characterized by heavy unemployment were not always those able to finance the care of the unemployed. The causes of unemployment were not local and frequently the wealth created by local industries, now dormant, had

been transferred to inhabitants of other states. A single industry operated in many states and cities. If it still paid dividends they might go in large measure to the states and cities not affected by unemployment in these same industries. The reference to unemployment is made here because through the back door of unemployment relief the federal government entered the cities and now occupies a seat in the parlor.

Great concern has been expressed for the unemployed and the low income groups. In spite of this most of the states, and to some extent the federal government, pay for relief from taxes on com-

TABLE 2

*Business Indexes**

	INDUSTRIAL PRODUCTION	FACTORY EMPLOYMENT (NUMBER OF EMPLOYEES)	CASH FARM INCOME	STRIKES BEGINNING IN MONTH	VALUE OF RETAIL SALES, DEPARTMENT STORES	WHOLESALE COMMODITY PRICES 1926 = 100		
	1923-5 = 100	1923-5 = 100	1924-9 = 100		1923-5 = 100	813 Commodities	Finished Products	Farm Products
March, 1929	118	105.3	102.5	68	113	96.1	94.8	107.2
March, 1933	59	62.2	**38.0**	106	58	60.2	65.7	42.8
March, 1936	93	93.0	67.5	185	84	79.6	81.3	76.5
March, 1937	118	107.3	81.5	614	93	87.8	86.4	94.1
March, 1938	79	87.4	67.0	274	86	79.7	83.4	70.3
March, 1939	98	91.0	64.0	220	88	76.7	80.3	63.8

* Source: "Survey of Current Business," U. S. Dept. of Commerce, May, 1939, pp. 5, 6, 8.

modities and property even though these types of taxes bear most heavily on the low income groups. Recently I made an analysis of the $164,204,449 spent by public agencies for social services in 1938 in Cook County, (Chicago), Illinois. First it disclosed that the money was raised by the following: City of Chicago, 6.1 per cent; Cook County, 6.3 per cent; State of Illinois, 25.6 per cent; the Federal Government, 62 per cent. The types of taxes used to finance these social services were next examined, disclosing the source of income to be: taxes on commodities, sales or services, $68,359,794; taxes measured by income, $36,266,169; taxes measured by value of property, $27,483,494; other revenues, $7,141,007; and other means of federal

financing including debt, $29,953,985. I cite these data primarily to disclose that we need to know which governmental agency collects the revenue to do a particular job and how it gets the money.

Local governments have been burdened by restricted revenues, increased service expenditures and a fluctuating relief policy. Their authority has been sacked by both the state and federal governments; their revenues have been curtailed and their expenditures increased by pressure groups typified in the first instance by the real estate interests and in the latter instance by the road interests and the organized educational lobbies. The local governments are now saddled with expenditures to maintain many non-essential public enterprises and the accompanying debt. Hundreds of communities have built institutions which they cannot afford to operate or whose debts they are unable to liquidate. The federal government relieved localities of one type of expenditure but burdened them with another by stimulating local spending.

Evils of Organized Minorities

Organized minorities have too much influence for the general good. From an economic system governed by the competitive price system, we have gone to a political system governed by competitive pressure. The power of pressure groups grows in part from the degeneration of the elected representative bodies; city councils, state legislatures and the national congress. The able and impartial leaders are hired by the pressure groups or do not care to risk their reputations, fortunes or prestige in the open political arena. The fact that groups, not individuals, have become important, accounts in part for the lack of leadership.

The federal government has fostered a great levelling process. It seeks to equalize economic conditions between sections of the country (North and South), between the states of the nation, between income classes, between economic groups (farmers and manufacturers) and between cities. The combined process of debt and taxation is used as the great leveller and the various social welfare acts as the great equalizer. A national government attempts to apply from one location uniform laws to a land that varies so greatly in topography, climate, natural resources, laws, traditions and racial composition.

There is quite general approval or acceptance of the government's intention to strengthen and reopen banks and repay depositors; to

foster building and loan associations, to conserve national resources; to preserve financial institutions such as mortgage and insurance companies; and to care for the unemployed, aged, and dependent. There is less general agreement on the construction of utility projects, and the subsidies to agriculture. The most justifiable criticism seems to be that many important agencies were hastily conceived and many agencies are incapable of successful administration. Whether we like them or not we should examine such things as unemployment compensation, old age pensions, competition of government with industry and if they seem certain to exist our efforts might well be centered on refinements in administration, or on inequalities in benefits. We might well seek alternatives. The real complaints arise not entirely from the spending of money but from the methods used in obtaining the revenues. There would be little opposition to governmental policies were it not for the fact that someone has to pay taxes.

The many minor things that might be done to promote recovery will be omitted here. There are too many fundamentals that need consideration. First, return to old fashioned personal and public honesty is the best way to bring about more harmonious relations between business and government, between employer and employee, and between business organizations. There is confidence only in an honest game where all cards are on the table. Closely allied to honesty is the need for *tolerance* of the thoughts, opinions and hopes of others. Unless individuals, business and labor are tolerant, the basis for a representative government does not exist. Tolerance of opinion is the first step toward the open discussion of problems in a democratic government.

Business has the responsibility for presenting a concrete, detailed, workable plan for relieving unemployment. If no such plan can be formulated then alternatives should be presented. The leaders of business should lay their affairs aside long enough to think through the situation in which they find themselves. They should think it through minutely, fully, impassionately. The affairs of the hour blind their eyes to the realities of the generation. They consider only the profits of the day, not the *system* which makes it possible for them to exist. But it is one thing to settle down comfortably in a private club with persons of like thought and social standing to settle business problems. Would it not be more useful for business groups to discuss with others, when no current strife interferes, the

relation of industry to the country as a whole. The production department must be efficient; the sales department learns what people will buy and changes the product accordingly; when financing methods fail to conform to economic conditions a business goes to the wall. Why then is it not reasonable for business to think through existing and inevitable social and political relationships and guide itself accordingly even for its own selfish purposes.

Business Should Formulate Recovery Plan

When the leaders of business have formulated a plan of recovery, or when they have other plans for the general well-being of the nation, they should be willing to stand up and fight openly for their plans. Business has been unwilling to formulate constructive plans and few business men have been willing directly and personally to lead their own battles.

A greater knowledge of the extent and causes of unemployment would be helpful. For nearly a decade now government has been considering its most important problem (relief) with too scanty a factual basis for remedial action or administrative purposes. Perhaps the decennial census of 1940 will help.

The labor situation undoubtedly holds an important key to the present industrial situation. If organized labor is to continue its present power, its leadership should be representative of the real interests of the workers. Autocratic power which does not represent the common good of the workers is no more excusable than arbitrary and unrepresentative political domination.

Restoration of the pride of the individual worker in his job would be a fine thing. This, of course, is limited by the extent to which he has a job where his handiwork can be identified.

Some greater incentives for proper and efficient administration of relief at the state and local levels is sorely needed. At present only a very limited group feel that they have any direct and immediate incentive for keeping relief costs at the lowest level consistent with the well-being of the unemployed. The federal and state governments should continue to help finance the relief program but both the state and local governments need greater incentives for more careful administration.

If the government has any intention of paying the national debt on the basis of our present currency and without excessive inflation, then the federal budget will have to be balanced soon by a reduction

of expenditures, an increase of revenues or a combination of the two. Even those who do not want to advocate a balanced budget should feel the need to know the objectives of the federal financial program.

Each of the levels of government needs to re-examine its powers and responsibilities. Each should be unwilling to surrender its rights merely for the sake of some temporary political or financial advantage. Only when government is kept close to the pople, and only when an informed public will support an impartial program for the common good, can we hope to have either political or economic recovery.

The federal government should decentralize its activities so that its agents and employees will interpret and administer the laws in accordance with the kind of people whom they are serving. It is impossible for any human being or group of humans to sit in Washington and try to apply the ramifications of present laws in an intelligent manner to the differing conditions in the forty-eight states. If the people who administer government live close to the governed there is far less danger of autocracy or bureaucracy.

Government should stop trying to be all things to all people. The spheres of activity taken by the government and by private interest will always be in a state of change. But the extension of government activity should be governed more by reason and less by pressure and social hysteria.

Finally the most important step in the recovery program would be the open announcement of a definite and consistent policy with respect to the major activities of government. Such a statement of policy, formulated jointly by business, labor, and government, or even by government alone, would permit all groups to labor wholeheartedly toward a real recovery.

Wholesale Cost of Water

By Charles H. Capen

NOT many years ago a young housewife, who had just moved from a farm to a suburban community, refused to pay the first water bill on the premise that water is free, being a bountiful gift from the skies. Apparently the water company serving that area did not agree with this viewpoint and there is little room for doubt as to what eventually happened in that particular case.

Usually it is not difficult to convince a complaining citizen that the clerical work involved and the maintenance of fire hydrants, and other visible physical equipment, require expenditures. But to persuade the same person that the collection of this water in reservoirs miles away, which nine times out of ten he has never heard of, much less seen, and conveying it underground by pipes, represents fixed and operating charges, is often a difficult matter.

Elements entering into the cost of water are not always thoroughly understood even by those engaged in the business of supplying this commodity. In many phases of water works the actual division of costs makes little difference. There are occasions, however, when it is extremely valuable to have a fairly complete knowledge of their breakdown. For example, it may be desirable for a municipality to investigate various extensions of a supply system and to compare these extensions with other possible developments. More often than not, such comparisons involve only the expenses incurred in delivering this commodity to the city limits.

Another situation is where a municipality desires to sell water wholesale to a neighboring municipality. In such an instance it is of vital importance to know precisely the cost at the point of delivery. This is not always readily obtainable, but a carefully kept set of

A paper presented on June 12, 1939, at the Atlantic City Convention by Charles H. Capen, Engineer, North Jersey District Water Supply Commission, Newark, New Jersey.

records, together with a good financial statement, materially aids any determination of this type. Such occasions have arisen in the metropolitan area of northeastern New Jersey, where the supply contracts have at various times demanded that a fair value be established, particularly in view of the fact that there is frequently competition between wholesale purveyors.

It is sometimes difficult for those not familiar with conditions in northeastern New Jersey to realize that with 148 municipalities supplied from 33 different sources, much of the water is transferred at wholesale under contract. When a contract expires, the purchasing municipality may elect to renew the contract, or to make another contract for different water. The motivating force behind such a change may be either price, quantity, quality, pressure, reliability, or a combination of any of these. While interchange of this sort is by no means as complete as it might be, partly on account of inadequate facilities, there are sufficient possible connections to make it reasonable for many changes in source of supply to be accomplished.

Costs in Newark, N. J.

The first of modern type contracts in this area was entered into between the City of Newark and the East Jersey Water Company on September 24, 1889, for a supply from the Pequannock River. This involved the alternate of an eventual purchase of the works by the City or a price of about $34.00 per million gallons as long as the contract remained in force. The contract included the option of purchase at a price of $6,000,000 and the option was taken up in 1900. Assuming carrying charges of about $6\frac{1}{4}$ per cent (which was about the total for debt service at that time) the annual charges would have been $375,000. For the 50 million gallons daily (m.g.d.) guaranteed, this would have given a fixed cost of about $21 per m.g. delivered at the City line, and adding an approximate charge of $5 per m.g. for operating, would have given $26 per m.g. as the gross expense.

It must be remembered that this did not include any of the later additions such as a large equalizing reservoir at Cedar Grove and the purchase of land on the watershed, both of which eventually served to increase greatly the total and unit figures. Furthermore, these unit costs are predicated on complete use of the supply, an event that never occurred prior to 1918. Naturally any well planned project is of such a size as to provide some margin for future expansion.

Long before 1918, it became evident that Newark would have to make plans for additional water, and in 1920 the Wanaque supply was started. At first Newark financed the project but eventually seven other municipalities joined. Only about one fourth of the total expenditure was made prior to 1925 and the balance was largely completed by 1930, when the supply was placed in operation.

In order to clarify this situation, figure 1 is given, showing the actual wholesale cost of water to Newark, not only for the entire period of existence of the Pequannock supply but also for the period just before its advent. The later portion of the period involves also

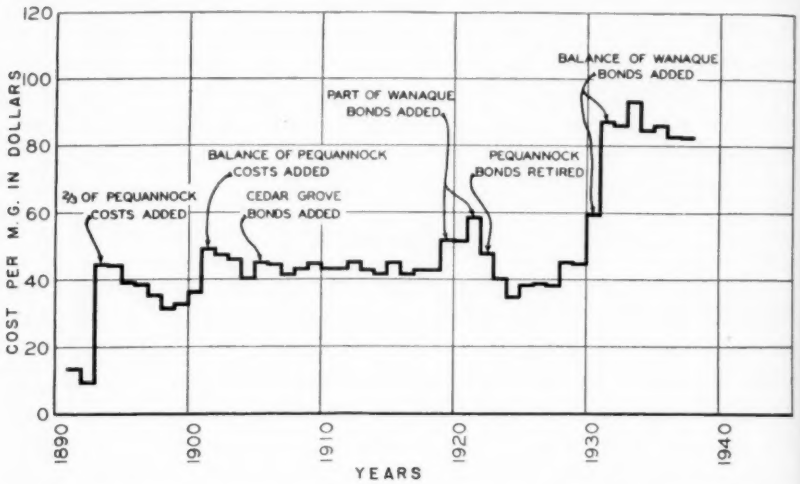

FIG. 1. Wholesale Cost of Water Delivered at Belleville or Pequannock Gate, Newark, N. J.

the financing of Newark's portion of the Wanaque supply. Values shown in fig. 1 include not only debt service but also operating and commercial expenditures connected with the wholesale portion of the supply.

Ordinarily it might be supposed that the retirement of the original Pequannock purchase bonds in 1922 would immediately reduce the price by a large per cent, but the issuance of watershed land purchase bonds, and the coincidental increase of Wanaque bonds, prevented full appreciation of this effect. However, it is believed that this curve is rather typical of what has occurred in similar instances in many parts of the country. An example is that given for Akron, Ohio, by LaDue (1).

An important fact to remember in viewing fig. 1 is that the costs are obtained by dividing total wholesale expenditures by total volumes of water withdrawn from the original source. Thus there is no recognition given to the loss by leakage or blow-offs along the transmission mains. Furthermore in the sale of water in bulk to other municipalities, the purveyor would be justified in adding an increment for contingencies. Some municipalities prefer to sell water at cost rather than lose the sale, particularly if water resources are more than ample, while others insist on a reasonable net profit such as any private utility would require. Newark's current price to others is $90 per m.g. and the city lost one customer when it tried to increase the price.

Elevation Is a Factor

Thus far nothing has been said about elevation. The Pequannock supply delivers water at a hydraulic gradient sufficient to take care of the three service levels in the city of Newark by gravity. It is the only large supply in this area thus equipped. The value of this service may be gained by studying the contract between Newark and Bloomfield, whereby the latter traded its right in the Wanaque supply for a similar right in the Pequannock in order to avoid pumping but pays an increment of $30 per m.g. for this added pressure. Similarly Glen Ridge pays Montclair $30 per m.g. for raising its Wanaque water to a high elevation at a pumping station owned by Montclair, thus avoiding the necessity of maintaining a separate installation. It may be seen therefore that a definite money value has been placed on water at higher elevations and consideration must be given to this in any comparisons such as those given in this paper.

Following the example of Newark, Jersey City made a contract with the East Jersey Water Company for a temporary supply from the Pequannock for charges varying from $43 to $22. Later the Jersey City Water Supply Company constructed the Rockaway supply for Jersey City with rates as follows: first 25 m.g.d. @ $36, next 5 m.g.d @ 34, next 5 m.g.d. @ 32, next 5 m.g.d. @ 24 and all over 40 m.g.d. @ $20.

The agreement contained a purchase arrangement whereby the City would obtain a 50 m.g.d. supply for $7,595,000. On the same basis as mentioned for Newark, this would give $31 per m.g. with full usage of the supply. Because full usage was long delayed

and because of additions to the system, this price has been exceeded during most if not all of the period of operation. The option of purchase was exercised by Jersey City, but litigation prevented full control of the source until about 1910.

Another contract of great interest was that of the City of Bayonne with the New York and New Jersey Water Company, made in 1894. Under a purchase clause the City, in 1918, acquired the right to obtain water from the East Jersey Water Company at the unusually low price of $19.50 per m.g. The company later found its cost exceeding the contract price and the case was adjudicated by the Public Utilities Commission, the rate being set by that body at $78 per m.g. as of January 1, 1923. This figure has been somewhat of a yardstick ever since and has been used as such for a new contract as late as 1936. It is still in vogue in several instances.

Sales at Less Than Cost

In the long run the sale of any commodity at less than cost is detrimental to business, and the situation herein recorded is no exception. There is one known instance in which a recent contract was made for wholesale water at $78 where the charge by any reasonable method of computation could be shown to be at least $100. In another, a municipality whose retail price to most consumers is $200 per m.g. even in large quantities, agreed to sell one large industrial consumer water at $100 rather than permit the consumer to drill wells.

To obtain true wholesale costs of water involves either a separate accounting system that is seldom employed, or a detailed analysis of actual expense in which some arbitrary judgment must be exercised to produce reasonable results. There are, however, a few instances where supplies for a district are so handled that wholesale costs are necessary because of the inherent nature of the system. One example of this is the Wanaque supply, hereinbefore mentioned, constructed and administered by the North Jersey District Water Supply Commission for eight participating municipalities.

The Wanaque supply was constructed on the basis of an estimated yield of 100 m.g.d. and each municipality contracted for a fixed share of the yield. Construction costs were, in general, proportioned to the share or allotment of each municipality except for portions of the transmission system not used by all of the participants. Bonds were sold by the individual municipalities and because of certain

indefinite phases of a few of the issues, it is not possible to obtain an exact accounting of all monies now necessary to meet the debt service on the original investment. However it is possible to arrive at an approximate estimate of this, as well as an accurate accounting of operating costs.

Under present conditions, with the supply being operated at about 70 per cent of nominal rated capacity, the average wholesale cost of Wanaque water is approximately $75 per m.g. for debt service, and $10 per m.g. for operating costs, or a total of $85 per m.g. Because of wide variations in the proportion of their allotment now being taken, the cost per m.g. varies for different municpalities and is estimated to be as low as $70 in one case and as high as $150 in another. The variation is further emphasized by the fact that the point of take-off for the different municipalities affects their participation in the transmission costs, the cost being the greatest for those at the far end of the line. When use of the system reaches full capacity, debt service will average $54 per m.g. and operating cost $8 to $9 per m.g., giving a total wholesale cost of $62 or $63 per m.g.

Costs in Large Cities of U. S.

In the belief that similar figures from other portions of the country might be of interest, a questionnaire was prepared, asking for data on wholesale costs, both fixed and operating, total water produced and population supplied. This was sent to all of the 93 cities in the United States having populations of 100,000 or more in 1930. Later some of the doubts indicated in the returns led to sending out a revised questionnaire. As defined for this purpose wholesale costs are intended to cover costs for the parts of the system up to the point where bulk transmission ends and distribution begins—usually at the city limits. Proportionate administration charges are also included.

Replies have been received from about three quarters of the supplies canvassed and although some of these are not in the desired form, much useful information has been received. The results are given in table 1. Since fiscal years vary, the year 1936 or 1937 was suggested so as to be sure to obtain a fully audited or reliable record. Furthermore yearly variations are not great, as demonstrated by many of the two-year records submitted. (See table 1 on next page.)

Much caution must be observed in the use of any of these figures. In the first place the population supplied is intended to include all

TABLE 1

Costs of Water in United States

CITY	YEAR	POPULATION SUPPLIED IN THOUSANDS	MILLION GALLONS DAILY	GALLONS PER CAPITA PER DAY	WHOLESALE COSTS PER M.G.				TOTAL COST PER M.G.
					Operating Costs	Fixed Charges	Depreciation	Total	
New York, N. Y.	1937	7,590 (a)	993 (a)	129 (a)	$7				$80
Chicago, Ill.	1936	3,987	1,060	266					40 (b)
Philadelphia, Pa.	1937	2,041	323	158					52 (c)
Detroit, Mich.	1937-8	1,989	247	123					69
Boston, Mass.	1937	1,456	131	90	31	$77		$108 (d)	
Los Angeles, Cal.	1935-6	1,301	155	119	4	38	$6	48	
Baltimore, Md.	1936	912	122	133	6	11	2	19	98
St. Louis, Mo.	1936-7	860	127	148	31	25		56	71
San Francisco, Cal.	1936-7	760	58	77	39			167 (e)	206 (e)
Wanaque Supply, N. J.	1937	750	71	95	10	75		85	
Washington, D. C.	1936-7	670	100	150				43	
Pittsburgh, Pa.	1937	630	90	143	17	38		55 (f)	
Buffalo, N. Y.	1937	600	121	201					45
Newark, N. J.	1936	590	58	98	26	57		83	125
Kansas City, Mo.	1936-7	485	62	126					116
Jersey City, N. J.	1937	408	53	129	12 (g)	34		46	89
Seattle, Wash.	1937	380	45	116					94
Portland, Ore.	1937	370	33	89					150 (h)
Houston, Tex.	1937	350	25	75	68	37		105	139 (i)
Denver, Col.	1937	350	61	175 (j)	15	33	13	61	108
Louisville, Ky.	1937	330	44	132	25 (k)		0		72
Dallas, Tex.	1936-7	320	28	88	10	26		36	170
Rochester, N. Y.	1937	308	27	86	8				92
Paterson, N. J.	1937	304	34	111	16	89	1	106	171
Atlanta, Ga.	1937	300	34	113	12 (l)				69
St. Paul, Minn.	1937	300	25	82	16				125
Memphis, Tenn.	1937	289	19	65					131
San Antonio, Tex.	1937	280	23	83					109
New Haven, Conn.	1937	260	28	105					122
Akron, Ohio	1936-7	248	22	90	16	59	0	75	166
Hartford, Conn.	1936	238	19	80	14	54	13	81	145 (m)
Omaha, Neb.	1937	218	28	130	40				160
Oklahoma City, Okla.	1935-6	216	14	67	23		0		142 (n)
Bridgeport, Conn.	1937	210	27	127	8	24	7	39	123
Nashville, Tenn.	1937	189	19	101					89
Richmond, Va.	1937	187	20	101	27	14	3	44	98
Springfield, Mass.	1936	178	18	103					151
Long Beach, Cal.	1936-7	170	15	88	25	13		38	131
San Diego, Cal.	1936-7	169	18	107	54	170		224	285
Trenton, N. J.	1937	163	17	103	30	6	0	36	78
Tulsa, Okla.	1937-8	155	15	97	16				144
Jacksonville, Fla.	1937	155	12	80					54
Des Moines, Iowa	1937	149	14	92					158

TABLE 1—*Concluded*

CITY	YEAR	POPULATION SUPPLIED IN THOUSANDS	MILLION GALLONS DAILY	GALLONS PER CAPITA PER DAY	WHOLESALE COSTS PER M.G				TOTAL COST PER M.G.
					Operating Costs	Fixed Charges	Depreciation	Total	
Yonkers, N. Y.	1936	148	14	93					$172
Flint, Mich.	1936-7	148	16	110	$32 (o)	$20		$52	76 (o)
Spokane, Wash.	1937	135	36	267	7	1	$3	11	26 (p)
Reading, Pa.	1936	131	13	98			0		86
Kansas City, Kan.	1937	130	16	126					141 (q)
Fort Wayne, Ind.	1937	125	9	76	50	24	13	87	154
Wilmington, Del.	1937-8	121	14	113					108
Elizabeth, N. J.	1937	120	7	59				90 (r)	274
Erie, Pa.	1937	120	25	205				42 (s)	74 (s)
New Bedford, Mass.	1936	120	10	79	26	37	0	63	139 (t)
Cambridge, Mass.	1937	118	12	102					67
Camden, N. J.	1937	112	16	145	33	9		42	62
Tacoma, Wash.	1937	111	43	387 (u)					51
Evansville, Ind.	1937	110	10	77					114
Lynn, Mass.		102 (v)							80
Lowell, Mass.	1937	101	6	57					

(a) Includes some areas served privately.
(b) Total without new construction = $29.
(c) Includes $15 depreciation.
(d) Wholesale without new construction = $59.
(e) Includes new construction.
(f) Production facilities 75% amortized.
(g) Includes amortization of $8.
(h) Includes depreciation of $19.
(i) Includes $35 for improvements.
(j) Includes irrigation water.
(k) Approximate.
(l) Omitting administration.
(m) Includes depreciation of $32.
(n) Omits auditing and legal costs and $40 for new construction.
(o) Includes depreciation.
(p) Includes depreciation of $8.
(q) Includes depreciation of $19.
(r) All water purchased at $90.
(s) Includes depreciation.
(t) Includes $43 for re-lining mains.
(u) Would be 273 without paper mills.
(v) 1930 census.

those served by the supply regardless of location with respect to city limits. For most cases these estimates are believed to be reasonably correct. The water produced is the volume of water withdrawn from the source or sources expressed in m.g.d., hence the gallons consumed per capita per day include all domestic and industrial uses as well as lost or unaccounted for water. Since practically all large cities furnish a supply to at least a portion of the contiguous suburban areas, and since the water produced and population served include these areas, the per capita rate of water consumption is correspondingly affected. In the few instances where separate figures have been submitted, the higher per capita consumption within the city limits where industrial and other uses are found, is always noticeable.

Revised Questionnaire Separates Depreciation

While many cities have accounting systems so set up that the wholesale costs are readily available, others have submitted reports with the expression of opinion that reasonable results could be calculated as desired while still others stated that such a separation would be impracticable for their systems. One of the particular difficulties is the marked variation existing in the methods used for allowing for depreciation. In some cases it is entered under operating costs and in some under fixed charges. Consequently the second questionnaire was worded so as to clarify some of these doubtful points and a separation of depreciation was asked for, where available, as well as the total annual cost of the system. (See outline of questions and information on opposite page.)

Another important item is the amount, frequently large, paid into city coffers. In the past few years water departments have often been called upon to bear more than their fair share of the burden of distressed finances of cities. The writer hopes at some future time to be able to point out some of the important phases of depreciation and contributions to municipal funds as both are items of considerable magnitude and importance regarding which all too little has been said.

In concluding this portion of the paper it should be noted that there are several large entities established primarily to construct a joint supply for several municipalities such as those at, in or around Boston, Hartford, Newark, Oakland and Los Angeles. Practically every large city supplies water to neighboring municipalities, but

SAMPLE FORM FOR REPORTING

1. Year of Report.....
2. Fixed charges for wholesale portion of supply .....
3. Operating charges for wholesale portion of supply (not including depreciation) .....
4. Depreciation charges on wholesale portion (if regularly charged off) .....
5. Total of 2, 3 and 4 (or 2 and 3, if there is no item 4) .....
6. Volume of water produced (M. G.) .....
7. Wholesale cost per M. G. (5 ÷ 6) .....
8. Total overall costs of department or company .....
9. Total cost per M. G. (8 ÷ 6) .....
10. Population supplied (estimated for year of report) .....
11. Per capita consumption (gallons per day) .....

.....
(Name of City or Company)

By.....

WHOLESALE COST OF WATER

In northeastern New Jersey much water is transferred under contract from some sources of supply to others, or to certain city limits where it is then measured through a large meter.

Interchange of water in this way requires a knowledge of cost, as frequently there is no profit in such transactions. A study is being made of this matter and it is desired to obtain comparable figures elsewhere. These figures are, of course, not those rates charged to normal large consumers of water, such as industries. In other words, this is "wholesale water."

"Wholesale Cost of Water" may be defined in this case as the actual cost per million gallons of water up to the point where bulk transmission ends and general distribution begins. Usually this division takes place approximately at the city limits.

Wholesale cost may properly include diversion, impounding, pumping, purification and transmission. Interest and sinking fund (or retirements) on bond issues covering these items, together with apportioned operating expenses and overhead would be the principal costs. If possible, depreciation should be given separately, as not all systems include depreciation. The total of these for a year (preferably 1936 or 1937) divided by the gross annual output will give the figure sought.

A large amount of detail is not necessary. All that is desired is an approximation. In addition, the population supplied and per capita daily consumption would be useful, together with total water department or company costs and total cost per million gallons.

there is no uniformity about the cost accounting or charges. Detroit, for example, made a careful analysis of costs and charges to its several wholesale customers and the inconsistencies thereby revealed are no reflection on the water department of that city but merely constitute a frank statement of a condition that exists throughout the nation.

Effect of Increase in Price Index on Wholesale Costs

Probably one of the best examples reflecting the effect of variations in costs of construction may be found in the case of New York City

TABLE 2

Relative Costs of Water for Various Sized Cities

1 POPULATION SERVED	2 PER CENT OF COST, DISTRIBUTION SYSTEM TO TOTAL COST OF ENTIRE WORK	3 CORRESPONDING PER CENT OF SUPPLY WORKS ALLOWING 5% FOR MISCELLANEOUS	4 GROSS REVENUE PER M.G.	5 PROPORTIONATE REVENUE FROM WHOLESALE WATER PER M.G.
5,000	72	23	$264	$58
10,000	68	27	230	62
50,000	54	41	167	68
100,000	47	48	145	70
300,000	39	56	117	65
500,000	35*	60	105	63

* Approximate: Not given in original table.
Column 2 from table by Metcalf, Kuichling and Hawley (reference 2).
Column 3 = 95 per cent minus Column 2.
Column 4 from curve by Capen (reference 3).
Column 5 is product of column 3 times column 4.

where segregation of the wholesale portion is somewhat more readily effected than usual. In New York City the Board of Water Supply constructs the supply system and then turns it over to the Department of Water Supply, Gas and Electricity for maintenance and operation.

The Catskill system of New York City was started in 1907 and the first and major stage was completed in 1917. The second portion was started in 1917 and was placed in partial operation in 1924 although final completion did not occur until 1927. Much of this work was done at pre-war prices and the total cost was $188,000,000

for a supply estimated at something over 600 m.g.d. Computed by the same method as other costs given herein, the cost per m.g. would be about $60 with full usage. The new Delaware River system for New York City is estimated to require the expenditure of $272,000,000 and to yield 510 to 540 m.g.d. Costs and yields were both computed some years ago and it seems likely that because of changes in the intervening years, the former will be greater and the latter smaller so that both changes will tend to increase the price per m.g. At any rate it seems likely that the ultimate cost will be at least $100 per m.g. The ratio of this cost to that of the Catskill system reflects both the increased prices at which the Delaware system must be constructed as well as its greater distance from the City of New York.

Relation of Wholesale Cost to Total Cost

Considered on a basis of investment only, Metcalf, Kuichling and Hawley (2) have made an approximation which is reproduced in table 2, together with other data tending to show the wholesale production cost of water. Columns 1 and 2 are taken directly from the original except that an estimate has been made for the population of 500,000 (which was not in the original). Allowing arbitrarily 5 per cent for miscellaneous costs, column 3 shows the corresponding per cent of total capital investment applicable to supply works only, i.e., it is obtained by subtracting column 2 from 95 per cent.

The writer (3) has obtained figures for gross revenue per m.g. from a large number of supplies, and the results corresponding to the populations in the table are given in column 4. Applying the per cent in column 3 to the values in column 4 gives a theoretical set of values for revenue from wholesale water as shown in column 5. This of course includes the proportionate share of net income and is therefore apt to be higher than should be normally used in a fair comparison of cost with figures given in preceding parts of this paper. This discrepancy, however, is usually not large although it may be appreciable in some instances. At any rate, cost and revenue, in any one case, bear a fairly definite relationship.

It is remarkable that the figures given in column 5 are relatively so uniform. This reflects a condition that is well known, namely, that small communities usually find supplies close at hand so that long transmission mains are unnecessary, whereas large cities are apt

to find that even though quantity production should lead to lower costs, these are to some extent offset by other factors.

Figures given in column 5 are not offered as empirical. It is sufficient to say that, allowing for net income, an approximate average cost of about $65 per m.g. is indicated as the general wholesale cost of water at present. However, it must be borne in mind that these figures are predicated on average investment costs over a period of years for supplies located throughout the nation, and that many of these costs not only were incurred at lower price levels than those now obtaining, but also reflect the retirement of many earlier bond issues.

While the figures for total costs of water given in column 10 of table 1 are believed to be as accurate and comparable as circumstances will permit, care must be exercised not to attempt too rigid comparisons. For example, many, if not most, large cities sell water wholesale to suburban communities which in turn do their own retailing. Obviously the total cost per m.g. does not include the net retail cost in such communities. Since the practice is nearly universal, it has to be assumed that this discrepancy is somewhat proportional for all of the supplies listed.

Conclusions and Summary

1. Per capita rates of consumption vary widely but show an unmistakable trend to increase with population.

2. Wholesale operating costs vary but show a general average between $20 and $25 per m.g. This cost is greatly dependent on type of supply and is usually lowest in the case of large gravity supplies from impounding reservoirs.

3. Total wholesale costs average about $70 per m.g. which checks fairly well with the theoretical results of table 2, column 5, thus tending to substantiate this figure as representative of present conditions.

4. Total costs average about $115 per m.g. and there is a definite indication that unit costs go down as total and per capita consumptions go up.

In the light of present construction costs, it seems inevitable that an upward revision of wholesale value of water per m.g. is in order. Tentatively this may be set at $80 to $100 and will unquestionably go higher in some instances. Of course, the small community that sinks a well near the center of distribution can occasionally produce water at an outlay that may be lower than the figures cited. Nevertheless

the writer knows of more than one case where recent local supplies have shown expenditures of over $100 per m.g.

The moral of this story is—do not hold water too cheaply.

The Division of Water of the City of Newark is under the departmental supervision of Mayor Meyer C. Ellenstein and City Engineer James W. Costello. Acknowledgement is hereby given of the cooperation of the Department in supplying the printed reports and public records from which the costs given in figure 1 were obtained. Further appreciation must also be expressed for the efforts of the many water works men all over the country who have spent much time in contributing figures that have been used in table 1.

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Increasing the Efficiency of Water Systems

By A. T. Cook

IN APPROACHING the subject of saving water, or as I would prefer to call it, increasing the efficiency of water systems, I believe that the first step is to define specifically the subject that we wish to discuss. The term "unaccounted for water" means but little, as it is too easy, with present day methods, to account for water. It is usually done by the simple process of guessing, or, as engineers prefer to call it, estimating; and we all know that estimating, like contractors' unbalanced bids can cover a multitude of unknown items, as well as some irregularities. Therefore, it is the writer's opinion that in discussing the question of system efficiencies, or as some would have it, saving water, the subject matter should include all water supplied by a system for which direct revenue is not received.

In making a study of the means and methods by which the percentage of unaccounted for water may be reduced, we should not confine ourselves to any one phase of the subject such as the cost of saving water, as such a definition is too apt to be misleading. The implication is that water should be saved and that additional cost will be encountered in so doing, while as a matter of fact, the operators of very few systems are concerned in saving water. They are concerned, however, in increasing revenues, eliminating useless waste, and in doing away with special privileges and discrimination. In other words, they are chiefly interested in increasing efficiencies. When we think of increased efficiencies we do not associate them with increased, but rather reduced costs. It is with the question of reduction of costs by increasing efficiencies that we are now concerned, and it has been the writer's experience that, with increased efficiency

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in organization and equipment, costs of operation are not only reduced, but revenues are materially increased.

Legally and theoretically, the only function of water supply is service. The courts have decreed that the waters of any political subdivision belong to the commonwealth; and we cannot sell to the people of that commonwealth what is already theirs. But practically, through the machinery used to measure service, water supply has entered the field of industry and commerce, and must be considered as such, even though its fundamental principle is service. Considered as a pure industry, water supply reflects but little credit upon management, for in the open field of competition, any manufacturer who loses from twenty to fifty per cent of his product between the factory and the consumer could not long remain in business. That such a condition exists in the operation of water supply is due to the fact that while it enters the fields of both industry and service, it cannot be confined strictly to either.

Service Distinguished from Wasted Supply

In the minds of the people there has always lurked the true, but impractical conviction that the water was theirs, or, as every water works man had heard it expressed by his consumers, "God's free gift to man," and with this conviction of their ownership has come the belief that they were privileged to use it, or to waste it at their own discretion. Throughout the history of water service there is written the record of a continuous conflict between service and economy, or, in other words, the record of the battle between an unthinking public that makes no distinction between service and waste, and the operators upon whose shoulders falls the duty of keeping the cost of service within reasonable economic limits.

In the earliest water systems no consideration was given to anything except service, and it necessarily followed that service and waste were synonymous. By earliest systems I do not mean those of the United States, but the systems of Rome, Spain and South America. A conduit, constructed at public expense, was brought into the central square, and to other convenient points in the city, and every man helped himself in accordance with his needs and desires. Had the development of water supply stopped at that point, we would not be troubled today with rates and losses. But the privileged soon conceived the idea of having private supplies brought into their houses and premises. At first these private sup-

plies were constructed at public expense, but as the number increased, the cost to the public became so great that each would-be private consumer was required to pay for the cost of his connection. He was, however, allowed the use of all the water his connection could supply, and the connections were allowed to run continuously.

Under such conditions it was inevitable that the available water supplies soon became inadequate for the growing demands; and various methods, such as reducing the size of the connections, were resorted to, in an effort to curtail the excessive waste. It is apparent, however, that these efforts were made, not to restrict the necessary use of water, but only to reduce useless waste. I have seen more or less dependable records which demonstrated that the total outputs of the earlier systems of South America were as high as one thousand gallons per capita per day for domestic consumption alone.

Flat Rate Superseded by Unit Price

These efforts to eliminate useless waste and still maintain the necessary service, or more broadly speaking, the efforts to maintain a balance between service and economy, led eventually to the establishment of the flat rate method of measuring the extent of the service rendered. Flat rates, with many modifications are still in use in many localities today. But the flat rate method has many faults, and it was only partially successful in reducing the enormous quantities of waste water that water systems were compelled to supply, and in bringing nearer together the economic items of expenditure and revenue. As it could not solve the problem of the increasing demand of water versus necessary expenditures, the next natural step was the introduction of the measurement system, under which the consumer was required to pay for all the water entering his premises at a unit price.

With the introduction of meters, water supply definitely entered the field of industry and commerce, and although the underlying principle of service has remained unchanged, water supply in actual practice became an industry. As such, the methods and principles of industry must be applied to its operation. In industry the problem is to maintain an economic balance between the income producing activities and the non-income producing activities; in water supply the economic balance between revenue producing water and non-revenue producing water. With the original conception and methods employed, and the cost of water today, the average family

would be compelled to pay several hundred dollars per year for the privilege of using, or wasting water, while the industrialist could use enormous quantities at a no greater expense.

Since the first aqueduct was built, the activities of water works men have been directed toward reducing the cost of water so that it might be available to every man in accordance with his needs. To accomplish this he has carried on a continuous battle against the three principal faults of water supply: waste, privilege and discrimination. Much has been accomplished, but perfection is not yet reached. Due to circumstances over which the water works operator has little, or no control, the cost of water at the source increased from year to year, and as the cost increases, the necessity for eliminating useless waste, privilege and discrimination becomes greater and greater. In the commercialized world of today, the only standards by which we may judge the efficiency of a water system are those of that world: service, quality and cost. Its success, whether it be private or publicly owned, must be judged by those standards. For that reason, it is the writer's opinion, that any discussion which deals with the cost and benefits of saving water must necessarily include all the non-revenue producing water, whether accounted for or not.

Unfortunately, the scope of a discussion of this kind is limited by the fact that the problems of every water system are different, and although the same principles of operation may apply, the relative values of the different items will vary to such an extent that no fixed rules can be laid down for every superintendent to follow. Thus, we cannot particularize. We can only generalize.

In every branch of water service there are certain losses whose magnitude will vary considerably in different systems. Their relative importance will vary also in accordance with the rates and the cost of water, so that the cost of correcting them and the value of so doing becomes the problem of the individual superintendent.

The principal losses that occur in a water system may be listed as follows:

Leakage,
Street Cleaning and Sewer Flushing,
Fires,
Illegal Use of Water Through Private Fire Lines,
Unauthorized Use of Water from Hydrants, and
Under-registration of Meters

Of the above, street cleaning, sewer flushing and fire protection

are not strictly losses, but necessary flat rate service for which some income is received. They are included because they may be classified as indirectly revenue producing.

Leakage Has Had Undue Attention

Leakage may well be called the bugbear of water works men, and as such, has been elevated to a position of more importance than it actually deserves. It was natural, that in the days when no income was received from the use of water and the right of usage was unlimited, the first step towards reducing waste was the elimination of leakage. This circumstance gave an importance to leakage that it has never lost. The most important loss caused by leakage is from property damage. Its extent will depend entirely on the character of the territory in which the leak occurs and is, therefore, the problem of each individual superintendent. Outside of property damage, the importance of leakage depends entirely upon the cost of water, yet I know of several companies which have spent thousands of dollars per year on leakage surveys to find leaks that actually cost them nothing, and whose repair was of no benefit whatever. Ignoring the danger of property damage, we may classify the different kinds of leakage in order of their importance.

A. Leaks in a gravity system where no water treatment is required. No economic loss as long as supply is adequate, and no property damage results.
B. Leaks in a gravity system where treatment is necessary. Economic loss is the value of the materials used in treating the water lost.
C. A pumping system where treatment is necessary. Economic loss is the value of the chemicals used in treatment and the cost of power for pumping the water lost. In a large system the above will be true but in a small system the amount of leakage may affect the personnel and equipment.
D. Systems where water is purchased. Here the loss per year, or per day will be the direct cost of the water lost, and the importance of the leakage will depend on the cost of the water.

In determining the importance of leakage I would suggest as a basis of discussion the following rule. Determine the cost of the water lost per year per thousand gallons, or per million gallons.

Capitalize that cost at 14 per cent, and the value of repairing the leak will be established. Fourteen per cent is used arbitrarily as an illustration, as it represents the approximate gross income that must be received by a water system to cover all expenditures.

In accounting for water the quantity of leakage is usually very much overestimated. A good example of the relative unimportance of leakage is the case of the Passaic Consolidated Water Company's system. For several years I was able to maintain an average of ninety per cent of the total output of the pumping plant sold through meters. The lowest percentage was 88.6 and the highest 92, yet during those years the consumption varied between a yearly average of 73 million gallons per day and 32 m.g.d. In a system with nearly four hundred miles of pipe lines, the leakage was so small as to be unnoticeable in the efficiency of the system. That is not true in every system, but with the continual improvement of the materials used in pipe line construction, leakage should grow less and less, and its importance decrease.

Street cleaning and sewer flushing are necessary services, for which some revenue is received, or some credit is given to the water department, but they are also the source of excessive waste in many cases. Firemen, especially in towns where the fire department is not professional, but volunteer, are inclined to waste water needlessly. Only by educating these men that when they waste water they are throwing away their own money, and by inducing them to cooperate with the water department, can useless waste be eliminated. Also there is a wide discrepancy between the revenue received for fire protection and the cost of providing it. The percentage of investment in a water system that is applicable to fire protection is ordinarily from twelve to twenty-five; the revenue received is usually from three to seven. It is an unbalanced condition that is worthy of study.

Illegal Use of Water Through Fire Lines

Although it is not generally recognized, the illegal use of water through fire lines may represent a large loss of income to the water department, especially in large or industrial cities. It may even go so far as the condition I discovered in one large city. There, an industrialist needing a large quantity of water need only pay for the installation of a private fire line. The line was metered, but the meter was never read, as it was impossible to make any charge for water used through a fire line. This procedure, or rather lack of pro-

cedure, was based on the assumption that as the use of water through private fire lines was prohibited, no one would use any. Still another city found that its loss of income from this source was $200,000 per year.

The question of private fire protection is in somewhat of a muddle. Some consider it a special privilege, yet the industrialists and the sprinkler system companies are complaining bitterly of the rates set by the public utility commissions. In all fairness, this service should bear its portion of the cost of operating a water system in proportion to the benefits received. To avoid abuse all private fire protection lines should be metered, not with a device that shows whether or not water has been used through the line, but with a meter that records the actual use. A certain allowance should be made for testing, and for the water that is actually used for fires. Other water taken through the line should be charged at regular rates, or even higher rates.

Unauthorized Use of Water Through Hydrants

Although the loss in either income or water is not large, the unauthorized use of water through hydrants is distinctly annoying. The real damage usually shows up in the cost of repairing hydrants, the difficulties, and oftentimes property losses resulting from finding fire hydrants not working when needed and in property damage resulting from leaving hydrants only partially closed. It can be corrected only through the cooperation of the police and fire departments with the water department.

Under-Registration of Meters

The under-registration of meters is the source of the loss not only of the greatest quantities of water but of the greatest losses of income as well. Water not registered by the meters represents a loss in the revenue that should be received from it, plus the cost of production. For example, if the selling price to the consumer is $300 per million gallons and the cost of production and distribution is $100 per million gallons, the total loss per million gallons is $400. The total yearly loss at the rate of one million gallons per day is $146,000. If we capitalize this loss, as in the case of leakage, at 14 per cent, it represents a minus value of over $1,000,000.

What is the cost of increasing the efficiency of meters? In my own experience I found that with improved repair of meters the cost

of maintenance was actually less. There is a reason for this, and to illustrate it I can cite the case of a large system for which in a consulting capacity I served on loss of income. This company had spent thousands of dollars each year on leakage surveys, but had never been able to sell more than 65 per cent of its total output through meters, although it maintained a large and expensive meter department. Tests of a large number of meters taken at random from the system and from the repaired meters showed them to be approximately 75 per cent efficient, and an examination of the meter records showed the average length of time that a meter remained in service without removal was slightly over two years. The cause of removal was usually stoppage of the meters.

The cost of each removal, repair and resetting was shown on the books of the company as $3.70, or $1.80 per year. It is generally conceded that a new, or properly repaired meter will register correctly on domestic consumption for a period of ten years. Using the same cost of repair and resetting, the extra cost of improper repair amounted to $1.55 per year per meter. This is an extreme case, but there are many systems where improper repair adds greatly to the cost of meter maintenance. In my own system, with an expenditure of $1,500, I was able to cut the cost of meter repairs to 60 per cent of the former cost, and to increase the percentage of water sold through meters from 80 to 90 per cent.

TABLE 1

YEAR	AMOUNT PUMPED	AMOUNT SOLD	PERCENTAGE SOLD	REVENUE
	gallons	*gallons*		
1937	270,858,015	155,846,000	57.51	$52,208.57
1938	223,757,700	158,312,000	70.75	59,875.50
	47,100,315	2,466,000	13.24	$ 7,666.93

I can cite here the gains that have resulted from an economy and efficiency program in the Borough of Hawthorne, New Jersey, after less than a full year of operation under the new method. The figures for 1937 and 1938 for consumption and pumpage are given in table 1.

There was also a saving of $5,329.20 in pumping expenses making the total net benefit $12,996.13, or 24.89 per cent.

It has been my privilege to examine and test meters taken from systems throughout the United States, and I regret to be compelled

to make the statement that the efficiencies of very few of them are anywhere near what they should be. There still remains much to be done in this line.

In closing I would like to outline briefly the various methods that in my opinion every superintendent should employ in order to obtain the best results in his system.

Outline of Methods for Efficiency

1. Every system should be 100 per cent metered and should have a master meter, or meters that will accurately record all the water entering the system.

2. The superintendent should forget that misused term "unaccounted for water," and make a monthly balance between the total quantity of water entering the system and the amount actually sold through meters. With this balance he will have one known quantity upon which he can base the efficiency of his system.

3. Organize and instruct his meter personnel so that every meter put into service will register better than 95 per cent of all the water that passes through it. Remember that eventually it costs more to maintain a sloppy meter department than an efficient one.

4. Work in harmony with the city departments: fire, police and public works; and impress upon the heads of those departments that any water that they waste is money out of the taxpayers' and their own pockets. Impress on the fire department the necessity of closing all hydrants well after using.

5. Watch closely for the unauthorized use of fire hydrants.

6. Keep a close check on private fire lines.

7. Be always on the lookout for leaks.

8. Install proper gages that will show, by pressure, rates, and so forth, what is happening in the system.

9. Work with the water commissioners or city council and secure their aid in eliminating special privileges and discrimination.

The above listed precautions do not represent any particular expenditure, but are only a question of organization. Every man in the department can be and should be trained to be continually on the lookout for leaks, unauthorized usage, or anything out of the ordinary.

It is surprising how soon, by using the proper vigilance, the superintendent and his staff will be able to tell immediately when anything unusual occurs in the system. The smaller the system the easier to

watch. I know one small system where the opening of a hydrant is shown immediately by the water elevation gauge in the pumping station. As a matter of fact, the W.P.A. was apprehended making free and unauthorized use of a hydrant within a half hour from the time it was opened.

The successful operation of a water system does not necessarily call for increased expenditures. Many systems have gadgets galore yet are not efficient. What is needed more than anything else today is a well-trained, vigilant personnel that is not bound by political horizons. The superintendent is sometimes handicapped by special privileges and discriminations due to Municipal ownership and political control. He is also handcuffed oftentimes by the existing rate structures. When a load is to be carried by a number of people, the more evenly that load is divided between them the greater the economy of effort will be. This is equally true of an economic load.

The cost of water service should be carried by every user of that service in proportion to the benefits received. Water rates today do not permit this to be so. They are still, in many cases, badly unbalanced. The water department that receives $300 per million gallons for water sold through meters and but $50 for water supplied by flat rates does not have a balanced rate structure. In that system will be found enormous losses, and useless waste, as well as special privileges and discrimination against certain classes of consumers.

It is impossible to reach any high degree of efficiency through mechanical perfection alone. Mechanical efficiency must be accompanied by cooperation from the civic bodies, civic departments and from the people themselves. Only by such cooperation can water service take its place without shame in the field of industry into which it has been forced by the commercialized world of today.

Discussion by *W. R. LaDue.* * Mr. Cook's paper, treating a special chapter in applied water works management, should command the interest of all superintendents interested in the problems involving efficiency of their systems. Testimony of this sort often affords the only clew to problems which, although commonplace, nevertheless are annoying, and sometimes intangible.

Mr. Cook states that "legally and theoretically the only function of water supply is service." If we grant that the *first consideration* is service, it follows that the *first obligation* is service at as low a cost

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as is consistent with the type of service demanded. If municipalities choose to enter the field of industry and commerce by ownership and operation of their water supplies, they must accept the rules which industry and commerce have decreed to govern efficient operation. Surely gas, electric, telephone and steam heating utilities have their losses and efficiency problems, and, if municipalities persist in granting "free" service, with the full knowledge that private enterprise receives payment for like service, then they must be willing to accept the criticism and lack of credit which accompany such inefficient types of rules for management.

The writer believes, as do many operators, that there is no such thing as "free service." He also believes that the citizens of a community get what they want—good or bad—whether it be efficiency or the lack of it. If this were not true, it would be indeed difficult to account for the waste, privilege and discrimination resulting from the "flat rate" system still in force, and popular, if you please, in many of our largest cities—and flourishing under the misleading guise of *benefits* arising out of municipal ownership. Mr. Cook has well said that, opposed to such practice, the commercial world exacts a higher type of efficiency, judged by service, known by quality and measured by cost.

Municipal water plants, in addition to supplying water at a price, provide many types of service and benefits, namely,

(a) Health and freedom from water-borne disease
(b) Sanitation by street and sewer flushing, dilution, etc.
(c) Domestic quality, softness, palatability
(d) Industrial preferment and inducement by rate
(e) Fire protection and safety
(f) Civic services to schools, hospitals, parks, public buildings, etc.

All these are services for which little or nothing is paid, assuming the ordinary bill under the water rate schedule is all-sufficient. It must be remembered that private enterprise also provides this service, but, in contrast, at a price devoid of privilege or discrimination; with particular reference to the last three items. If we are to save water, we must remember that "easy come, easy go" and, further, that many a good show has been ruined by too many complimentary tickets. "Free Water" is a complimentary ticket.

How then shall we proceed to account for value given? Four points will be discussed below:

(1) Eliminate the "flat rate" system so that nearly all services become revenue-producing. Thus a real effort is made to bring the ratio of non-revenue-producing service to revenue-producing service near zero. With no meters, water can be and is wasted, at a loss to the efficiency of operation of the entire system. Meters never discouraged legitimate use of any quantity desired, but they do reduce waste resulting from needless and unproductive consumption.

(2) Increase the mechanical efficiency of the system by *increasing* revenue-producing water. In this we are not concerned with increasing the average income per million gallons since that involves the rate schedule, but we *are* interested in making existing services pay for water used. This increase in mechanical efficiency can be accomplished only by increasing meter registration by keeping meters in constant good repair. Loss of revenue due to under-registration of meters can be reduced by proper sizing of meters. Akron is 100 per cent metered. Too often, in the larger commercial and industrial buildings, meters properly sized when installed, have become over-size, or miss-sized, due to change in conditions dictating the use of water—and such meters are potential losers of water revenue. If the consumer owns his meter it is almost impossible to make him scrap or remove it and purchase and install a smaller one to increase his own bill. The solution of course is for the water department to own all meters, thus allowing the department to change the size when increase or decrease in the use of the water demands it.

Experience in Akron

In Akron, 432 industrial and commercial meters, 1½-inch and larger owned by consumers, account for 38 per cent of all the revenue-producing water. (The city owns no large meters). For the past twenty years these meters have been under the constant supervision of a special organization of four men (office clerk in charge, reader and two repair men). We have found, from the increase in the efficiency resulting that this special organization fully justifies its existence and its expense. Meters are read frequently, some daily, some twice a week and some weekly. In this way meters are known to be operating and registering, and, if they should fail, estimates can be made on the basis which the consumer sees is logical and bills can be rendered which he will not contest but will pay.

In the consideration of under-registration of smaller meters, ⅝- to

1-inch in size, conditions are considerably different. Let us consider what a 2 per cent increase in registration by the smaller meters will represent in increased revenue. In Akron these small meters in 1938 accounted for 62 per cent of all the revenue-producing water. This would be a more fertile field if you could forget the so-called "minimum bill." Of the water recorded by small meters 39 per cent was used by consumers paying the minimum bill, having used the minimum amount allowed, or less. Thus a 2 per cent increase in registration in this small meter group would produce slightly over 1.2 per cent increase in revenue from these meters, or a 0.75 per cent increase in total revenue-producing water. With 56,000 meters in Akron it is estimated that such an increase would amount to about $9,000 per year. An additional expenditure for meter repairs producing these results is easily justified. Our entire meter repair bill at Akron in 1938 was only $10,351. On the other hand, new capital could be justifiably invested in the purchase of any new meter which could insure such additional registration reliably over a period of years. This "minimum bill" practice presents a real problem in the developments of rate structure, and is as variable as the number of cities involved. The larger the number of minimum bill consumers, the closer a schedule approaches the old "flat rate" in principle. Meters on minimum bill service may be justly termed "flat rate" meters, so far as increasing revenues is concerned, and are installed only and practically for psychological reasons.

(3) Increase the mechanical efficiency by *reducing* "total" water. The two factors here involved are:

(a) Wastage by city departments in street flushing, sewer flushing, fire department use, construction work, etc. The solution is a matter of cooperation among the departments and the remedy cannot be discussed at length here, except to urge cooperation to that end.

(b) Leakage. In Akron we have about 645 miles (5,300 inch-miles) of mains and hydrant runs ranging in size from 4 to 48 in. and in age from 1 year to 58 years. With 200 gallons per day per inch-mile—a not unreasonable allowance—the minimum leakage allowable is 1.06 m.g.d. or about 5 per cent of all water pumped. Let us see what a reduction of 1 m.g.d. would save. A simple analysis of the problem would indicate that the only loss is the cost of producing the water. No loss of revenue is involved since the product apparently

has no available market. Assumed also is the item of complete plant adequacy. In Akron, chemicals for treatment and fuel for pumping average $6.50 per million gallons, and in one year this amounts to $2,372. Present worth of this figure at 8 per cent over—say a period of 20 years—is $23,250, which sum could be justifiably spent for detecting and repairing leaks.

(Mr. Cook states that 14 per cent "represents the approximate gross income that must be received by a (private) water system to cover all expenditures." With private companies vitally concerned with revenues this may be required; however, in the consideration of the municipal plant, I believe 8 per cent to be ample.)

I wish to submit, however, that leaks, to be of most value when discovered by leakage surveys should be fairly small in size, hard to detect and non-damage producing. Large leaks more generally reveal themselves early due to the damage usually involved and are not of sufficient life to justify the required investment for a survey when considered on a long-time basis. The usual assumption is that any reduction in leakage is a continuous gain in efficiency not to be again lost.

(4) Eliminate "free water" and "free service," insofar as it is possible by demanding payment for services rendered. If payment cannot be secured, at least a measure of reward may be obtained by metering all non-revenue producing consumption and rendering bills for water, hydrant rentals and the like.

Faborable public opinion can be secured by the presentation of the facts by the superintendent or members of his personnel, by the licensing of operators, by newspaper publicity and by civil service reform, all of which are potent instruments to gain public confidence. Some day the lesson will sink home and the demand of the public for business principles in municipal water supply management will be well-answered by efficient operation, backed by potent public opinion.

Social Security for Water Works Men

By Dale L. Maffitt

THE theory of social security is not new in America. Most states, insofar as their resources permitted, were meeting the problems of child welfare and public health, care of the needy blind, and needy aged, for some time prior to 1935, when federal social security legislation was enacted.

Governmental old-age insurance, which has long been established as a feature of workers' security systems in other countries, was new to the United States. The American philosophy of individualism had left the matter of saving for old age entirely to the worker—with disastrous results. Small savings cannot be invested advantageously; bank failures, business depressions, and unemployment often defeat the most carefully organized plan for individual saving. The feature of old-age insurance in the Social Security Act of 1935 was designed to meet this problem by means of cooperation between the federal government and the states in meeting needs that heretofore had been left to charity or to piecemeal and haphazard provisions by individual cities, counties, and states. Through a national old-age insurance system administered by the federal government, effective January 1, 1937, "industrial and commercial workers have an opportunity to build up a retirement income, based on their own industry and assured by the federal government."

The relationship of water works employees to this legislation has not changed since the meeting of the American Water Works Association two years ago, at which we presented a paper on the subject (Jour. A. W. W. A., **29:** 1111 (1937)). At that time the federal Social Security Act had recently been put into effect, the purpose of which was to provide against the uncertainties of the future, both as

A paper presented on June 12, 1939, at the Atlantic City Convention by Dale L. Maffitt, General Manager, Des Moines Water Works, Des Moines, Iowa.

regards unemployment and old age. The ideal to be attained by that act is very desirable.

Old-age insurance is a big undertaking designed to cope with one of the problems which modern large-scale industrial development has accentuated. As organized under the Social Security Act it represents a partnership into which workers and employers and the government have entered to insure for millions of persons a greater degree of individual and social security than any of the three could effect alone.

Statistics of Federal Program

Since the federal old-age insurance program became effective on January 1, 1937, more than 43,900,000 accounts have been established for industrial and commercial workers.

Under this program, monthly benefits, which begin to be paid in January, 1942, will range from $10 to $85 for eligible employees retiring from employment at age 65. Single cash payments, equal to 3½ per cent of wages received in covered employment since 1936, have been made since January, 1937.

A press bulletin of the Social Security Board reports that on December 31, 1938, old-age insurance claims certified for single cash payment totaled 266,906 in number and $11,755,275 in amount, or an approximate average payment of $44.

However, water works employees are specifically exempted from participation in benefits of the act under Section 210, which defines "employment." Exemptions listed under Section 210 (b) include "service performed in the employ of a state, a political subdivision thereof, or an instrumentality of one or more states or political subdivisions."

Most water works organizations are municipally owned, which puts them on the exempted list. This results in water works employees being at a disadvantage as compared with employees of industry who participate in the benefits of the Social Security Act. They have no assurance of protection in old age aside from that provided by their own foresight, and far too often we see old people dependent because the savings they so carefully put aside to care for them in their last years have been lost in bank failures or other losses beyond their control.

Since the Social Security Law went into effect, effort has been made to bring about improvements in the law and its administration.

The Advisory Council on Social Security was created in May, 1937; its members were appointed by a special committee of the Senate Committee on Finance, in cooperation with the Social Security Board. With the purpose of extending the coverage under the act, the Council has recommended that employees of national and state banks, seamen, and employees of nonprofit religious, charitable, and educational institutions be included. The Council has also suggested that the system be extended as rapidly as feasible to include additional groups now excluded, such as farm labor, domestic employees, and self-employed workers. It may be that at some time water works employees will be included under the act, but there is no indication that this will happen very soon.

Current Hope Is in Local Organization

Thus it is apparent that if water works employees are to be assured of security in their old age it must come through an organized plan within their own water works organizations. During the last two years considerable thought has been given to the problem, and in a number of states the matter has been brought before the legislatures with the idea of getting enabling legislation which would permit water works companies to work out a plan of old age insurance for their employees either within their own organization or through an insurance company.

The objective of a retirement system for water works employees is not entirely social. The average person thinks of a pension plan as something designed to provide against insecurity during old age and nothing more. This is not the case. A sound retirement system pays for itself in economic value in that employees who are too old to render efficient service may readily be eliminated from the payroll. It also serves to attract high grade personnel by providing benefits similar to those made available in industrial concerns. An adequate retirement system which automatically retires older men in administrative posts at a certain age opens up the hope of advancement to younger men, thus stimulating them to greater efficiency. The constant influx of younger men into administrative positions also brings new ideas and methods, which are necessary if municipal utilities are to keep pace in efficient operation with industrial concerns.

William H. Sherman, field consultant, League of Minnesota Municipalities, in his thesis "A Suggested Retirement System for

Employees of Small Municipalities," published in *Minnesota Municipalities*, March to July, 1938, states, " . . . since reasonable permanency of tenure is necessary in governmental service if suitable men are to be attracted and retained and since superannuation is a natural corollary of permanent tenure, the establishment of a sound and adequate retirement system seems to be the best remedy for the bad situation which exists in its absence."

Louis D. Brandeis, as quoted in Lewis Meriam, *Principles Governing Retirement of Public Employees*, has written, "Given the status of employee for life, the need of an old age pension is obvious. The employee needs the pension because he cannot—or at least does not—provide adequately from his wages for the period of superannuation. The employers need a comprehensive pension system because while the presence of the superannuated employees in a business seriously impairs its efficiency, the dictates both of humanity and of policy prevent discharge unless their final necessities are provided for. The demand for a pension system grows more pressing as businesses grow more stable; for in older businesses there is a constant tendency to accumulate superannuated employees. The demand becomes particularly acute when businesses grow large as well as old; for then it becomes difficult to provide for the individual needs of the employee."

Public Favors Retirement Systems

It is evident that the need for and value of retirement systems is generally accepted. Pension systems for policemen and firemen have long been established. In recent years teachers' pension systems have become more numerous. Many industrial firms have voluntarily established retirement systems for their employees.

Since water works employees are not covered by the Social Security Act, it becomes necessary to solve their problem of old-age retirement some other way. Assuming that enabling legislation of the state governing body permits public employees to organize retirement systems, the solution is only begun. An actuarially sound system is absolutely imperative or the whole thing will become overburdened and collapse in a few years after payment of benefits starts.

A pamphlet prepared for the Municipal Finance Officers' Association by I. Rafkind, staff member, entitled "Retirement Systems for Public Employees," gives a detailed and well-worked-out study of the problems involved in establishing a pension plan for a munici-

pality. A brief survey of this treatise is well worthwhile, for the principles which apply to a municipality also apply to a water works organization.

Retirement Systems Classified

Mr. Rafkind classifies retirement systems in several different ways. As to source of funds, they may be "non-contributory," with the municipality paying all the costs, or "contributory," with the employees paying all or part of the costs. The most acceptable plan is jointly contributory, with the employee and the municipality sharing the cost.

Classified as to method of meeting the liability, retirement systems may be on the "cash disbursement plan," under which benefits as they become due are paid out of current revenues; or the "actuarial reserve plan," which the law requires insurance companies to follow, where an actuary computes the future cost of benefits on the basis of mortality and other experience tables. Under the latter plan a reserve is set up, the annual contribution to which is determined by the actuary. As time goes on compound interest shares a large part of the cost. The "cash disbursement plan" is dangerous because, while it seems less costly for the first few years, as more and more employees are retired the cost increases at an accelerating rate, the peak burden not being reached for years. Sooner or later it becomes insolvent. While an actuarially sound plan is more costly during the first few years than a cash disbursement plan, it does provide for the ultimate cost of benefits in advance, thus avoiding undue burdens to future management.

Procedure in Establishing Retirement Systems

The first step in establishing a retirement system is determining that there is statutory authority to do so. If specific authorization is necessary, or if a uniform authorization exists, as in Massachusetts, a qualified attorney should advise what legal steps must be taken. Next a competent actuary should be requested to present an outline showing the probable cost, the various alternatives that may be selected, together with the effect of selecting each alternative. A plan for future employees should be considered first of all, since a permanent plan is designed primarily for them. Then consideration may be given to a plan for present employees. Since the plan is new

and no contributions have been made toward meeting the cost for present employees, the system probably starts with a large deficit, if the same benefits apply to present, as well as future employees. This accrued liability must be provided for in making the estimates of cost.

If possible there should be one retirement system for all classes of employees, although benefits, rates and retirement ages may vary. Temporary and part-time employees should be excluded. Elective officials have commonly been excluded on the ground that their tenure is not permanent. However, if the retirement system provides for return of a member's contributions in case of dismissal or resignation, there seems no reason for excluding elective or appointive officials.

Membership in the system should be compulsory for all future employees. Membership for present employees may be optional, but there should be a limited time in which they are allowed to join the system.

Classes of Benefits Defined

Mr. Rafkind defines four main classes of benefits which a retirement system may attempt to provide: (1) retirement benefit on account of age; (2) disability benefit on account of accident incurred in line of duty; (3) disability benefit on account of ill health; (4) death benefit in line of duty or otherwise. "The primary purpose of a retirement system is to provide the superannuation benefit. Employers must realize that in retiring aged employees they help themselves as well as the employees by removing 'hidden pensioners'—employees who have passed their peak and are being paid more than their services are worth. Thus the retirement age should attempt to approximate the age which represents the limit of the employees' useful service."

A retirement allowance should best be viewed as a provision for old age and for the promotion of efficient service, and not as a reward for services rendered; and should thus be granted on the basis of age, and not years of service alone.

The amount of benefits paid should be related directly to the amount of contributions. The financial status of a retirement system can be controlled more readily and kept on a solvent basis if the annuity benefits are based on actual accumulations.

For the administration of a retirement system a retirement board or board of trustees is usually created. A secretary or executive officer must be employed to maintain necessary records. These records should be developed with the advice of a competent actuary and an accountant, and should provide detailed information so that obligations can be anticipated, benefits determined, and the financial operations of the system audited. An actuary should be employed throughout the existence of the system. In establishing the system his function is to determine initial rates and establish records necessary for actuarial examination. As time goes on his function is to watch the operation of the system and recommend such changes as may be necessary to keep the system solvent, and also such changes as may be desirable to meet changing social, legislative, and personnel conditions. Supervision of a retirement system by the state insurance department is quite desirable.

Needless to say, the manner in which reserve funds are invested can determine the success or failure of a retirement system. Investments legal for savings banks and trust companies are ordinarily satisfactory. Interest earnings from the reserve fund are important since interest bears a large share of the cost of the system, but the element of safety is of first importance in selecting investments.

Cost of a Retirement System

The cost of a retirement system depends upon a number of factors: age distribution of employees, rate of retirement, type of benefits selected. Actuarial estimates can determine rather accurately what the cost will be. The normal cost to municipalities participating in the New York State Employees' Retirement System was 3.09 per cent of payrolls in 1933. The average contribution by employees was 4.94 per cent, making average contributions total 8.03 per cent. The actual rate varied from 3.06 per cent for a person 12 years old, to 8.13 per cent for an employee aged 59 or over.

On June 8, 1938, the employees of the Department of Water and Power of the City of Los Angeles, California, were given an opportunity to subscribe to, and apply for membership in, the Water and Power Employees' Retirement, Disability and Death Benefit Insurance Plan. The system was authorized by special charter amendment. The estimate of the average cost, for the above benefits, was set at 6.85 per cent of insured payrolls to the employee, and 6.61

per cent of insured payrolls to the Department. The estimated percentage of payrolls to be paid by the employee to the retirement fund alone varied with age from 3.60 per cent for males at age 20, to 7.42 per cent at age 64; and from 5.28 per cent for females at age 20, to 9.95 per cent at age 59. The estimated percentage of payrolls to be paid by the Department to the retirement fund varied from 3.75 per cent for males at age 20, to 7.73 per cent at age 64; and from 5.49 per cent for females at age 20, to 10.35 per cent at age 59. Disability and death benefit rates were much lower and varied with salary as well as age. It should be of interest to all water works organizations to watch the operation of this plan.

Bills in State Legislature

Two bills relating to this problem were presented to the Iowa Legislature in its last session. One was definitely a pension bill, and was designed to authorize pensions to employees of municipally owned utility plants. Water works, light plants, heating plants and other municipally owned plants were included; and the amount of the pension was to be based on years of service. Under this proposed bill the pensions were to be paid out of current revenue of the respective plants establishing the system.

The second proposed bill was designed to authorize the board of trustees of municipally owned water plants in cities of 50,000 inhabitants or more to establish a plan for purchasing group insurance for employees. Both of these bills were referred to committees and indefinitely postponed.

The average small municipality has an insufficient number of employees to spread the risk of a complete retirement system. A solution in this case is to participate in a sound state retirement system. This has proved successful in New York state. Another solution is to join with other local units to organize and administer a combination plan. Still another method is to purchase group insurance through a reputable insurance company.

Hence, social security for water works employees may be considered practicable. In the light of recent social developments, it seems logical and sensible that water works employees should have the same assurance of old-age independence that the federal government is giving employees of industry. It is a problem which is well worth the attention of all water works men.

Discussion by William W. Brush.* In his paper on "Social Security for Water Works Men," Dale L. Maffitt has pointed out that water works men are not eligible for the benefits under the Federal Social Security Act, has clearly set forth the advisability of some pension or old-age security plan being made available for the water works personnel who are in the municipal or state service, and has reviewed what is necessary to be done to establish an actuarially sound plan.

The space allotted to this discussion will be used to consider the subject "What appears to be the most effective plan to obtain for municipal water works employees old-age security."

In the following discussion, the word "municipal" or "municipality" is used to indicate either a city or a subdivision of the state, including at times the state itself, as the various states have water supply systems in connection with some of their activities.

Various Old-Age Security Plans

The various plans under which a municipal water works employee might obtain old-age security would include the following:

1. A municipally established and operated pension system.
2. A state established and operated pension system with municipalities having the option to enter such systems.
3. Extension of the Federal Old-Age Act provisions to include employees of states and political subdivisions thereof.

The question of whether the plan is to be set up through the utilization of a life insurance company or financed directly by the public agency is not considered as this is merely a detail of any plan.

Pensions Established Directly by Municipalities. Where this plan has the backing of public opinion so that it will be adopted by the municipality, it probably represents as satisfactory a plan as any that can be devised for the employee, although the state plan with the municipality participating has the advantage of the entire state resources being back of the plan instead of simply the resources of the city. Such a plan, together with all other plans, should be one where the contributions are made both by the employee and by the employer, and presumably in approximately equal amounts.

As can readily be seen, there are innumerable details in any of

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these plans that must be worked out, the most important being the amount yearly contributed to the pension fund and the amount of the benefits to be secured therefrom.

All such pension systems should be a contractual obligation on the municipality.

State Pension Plan with Participation by the Municipality. This plan has been successfully adopted in New York and Massachusetts and probably is the most desirable for the smaller municipalities. The state sets up and finances a plan. The municipality after accepting the plan, is required to meet the financial obligations under the plan, the state assuming the obligation to pay the pensioner the amount that he may be entitled to under the plan.

Extension of the Old-Age Security Act to Cover Employees of States and Subdivisions thereof. The probability is that the employees of states and their political subdivisions were excluded from the federal social security plan mainly due to the question of the constitutional power of the Federal Government to tax the states or their political subdivisions for the percentage of the payroll which would have to be paid by the employee and by the employer under the Old-Age Security Act.

The greater portion of the obstacles in the way of including the employees of states and their political subdivisions in the federal plan appears to have been swept away by the recent decisions of the United States Supreme Court holding that the Federal Government may tax the salaries paid to employees of states and their political subdivisions. It is believed that the federal act might be amended so as to permit each state to accept the provisions of the plan as applying to that particular state and then the water works, together with all other municipal employees could secure the advantages of the federal pension or old-age system.

Plan for Action

Let us now consider what water works men can or should do to secure the old-age pension to protect them and their families when they are no longer able to perform their duties satisfactorily.

The writer believes that the American Water Works Association should take the leadership for the water works men in endeavoring to secure old-age security for the municipal water works personnel.

An outline of a plan that he believes to be practicable of attainment is as follows:

1. Undertake to secure the cooperation of all of the organizations throughout the country which have to do with municipal or state governments and their employees. The objective of this cooperation is to be the passage of an amendment to the Federal Social Security Act so that all state and municipal employees can come under the provisions of that act.

2. Prepare a draft of an act to establish state pension systems which would be available as an aid to the smaller municipalities in those states where it seems feasible to secure public support for legislation that would set up a state pension system which would include all employees of municipalities that were willing to join such a system.

3. Lend the support of the Association and its sections to all sound pension movements for public employees that may be developed in the future.

The writer believes that our Association can and should be an important factor in securing the federal old-age benefits for the water works men and also in setting up sound pension systems in the various states which do not now have such systems. Obviously, such activity to be effectively prosecuted would necessarily cover a long period of years before finally accomplishing its objective.

Maintaining Public Confidence

By Thad M. Erwin

THE business of maintaining a closer relationship between a utility and the public is a governing factor in that utility's success or failure; and this closer relationship is best built up by the employees of that utility giving prompt, courteous, and considerate service at all times, with a constant effort to give the consumer a logical explanation for the making and following certain rules and regulations governing the water service.

While the public has become more critical regarding the taste and quality of the water supply and the service rendered, there is unquestionably a considerable lack of understanding of the technical difficulties and heavy responsibilities involved in connection with the operation of a water works system. This is one of the difficulties we are endeavoring to correct through various publicity programs; for the good will and understanding of our consumers is a valuable asset and we are endeavoring to cultivate this spirit in every way possible.

We want the public to realize that our water department has done more than furnish a water supply to its citizens. We want them to know that it is through the development of an adequate and dependable water supply that the economic security of the community has been assured. Water is one utility for which there is no substitute; if the water supply is limited, then the growth of that city is limited in a corresponding degree. Our municipal water system is the property of our citizens and we want their cooperation and support in all our undertakings—whether large or small—and we want them to

A paper presented on June 14, 1939, at the Atlantic City Convention by Thad M. Erwin, Water Business Agent, Bureau of Water Works and Supply, Dept. of Water and Power, Los Angeles. Questions in the paper were submitted by M. F. Hoffman, Asst. Superintendent, Commercial Division, Dept. of Water Works, Cincinnati.

point with justifiable pride to their water system and the things it is doing to add to the health and happiness of the community.

The operation of a public utility, like the holding of a public office, is in the most positive sense a public trust. It is only through a thorough knowledge of the accomplishments and aims of their water department that citizens are able to test the efficiency of that organization and measure its services to the community; and it is the duty of each and every employee (in either field or office) who has a direct contact with the public, to encourage a spirit of friendly cooperation in the consistent promotion and development of any activity that will benefit the community as a whole.

On the part of our executives, such a program calls for every effort for scientific research and every effort to educate, to improve, to broaden the interchange of ideas with others in the same industry; to do all things that may give a more solid foundation and more far-reaching contacts in the community. When our consumers realize this, we feel sure that we will find on our balance sheet a good-will asset of inestimable value.

As our organization has grown, we have endeavored through an intensive educational campaign among our employees, to inform the public on the whys and wherefores of our standard practices, particularly on those that may be misunderstood.

In our relationships with our consumers, we, like every other utility, receive many complaints—some serious and some very trivial. But we give every complaint our sincere consideration and a thorough investigation, not only to assure satisfaction to our consumers, but for our own benefit as well. Some constantly recurring complaint, when thoroughly investigated, may disclose an unforeseen opportunity for us to improve our standard practice in the matter.

Questions by Hoffman; Answers by Irwin

A few questions and answers, as applied to some of our standard practices in the interest of the consumers may elucidate the foregoing. Since billing and collecting procedures and the public's reactions to them are of interest to all of us, we shall start there.

When are your water bills delinquent, and what is your regular procedure for collections? Water bills are due and payable within fifteen days after presentation. After the fifteen days, all unpaid accounts automatically receive a three-day courtesy notice as a reminder that payment should be made; and if not paid within that

time, the account is considered as delinquent and water service is discontinued.

Do you ever change the reading date on a meter at the consumer's request? This request could not be granted, as we read meters in various sections of the city on, or near, the same date each month.

If a consumer calls and says "I have several pieces of property here in the city; why can't you send all my bills at one time?," what would be your answer? Our service records are kept by address rather than by name. As just mentioned, meters are read in different sections of the city on different days of the month, and the cost of trying to bring the bills together for each consumer would be prohibitive.

Suppose a consumer having several services on one property asks that the consumption be combined for billing; can it be done? Yes. Where because of special conditions more than one service connection is desired or required to provide adequate service, and the same is for an individual consumer, on the same property, and not for separate tenants, this consumption may be combined for billing; but an additional charge of $1.00 will be made for each additional service so combined. This combination is only applicable to premises not divided by public streets and highways.

Suppose a consumer claims his water meter has not really been read for months? We arrange a definite appointment for a special reading to compare with the last regular reading; and we also instruct the consumer so that he may read his own meter and verify future readings.

How do you bill water consumption when it is discovered that the meter does not register? When we find that a meter has failed to register, the charge for water is based upon the average consumption for the three preceding months during which the meter is known to have registered correctly, or on the consumption as registered by the substituted meter. Consideration is also given to the volume of business, seasonal demand, and any other factors that may assist in determining an equitable adjustment.

How do you handle a consumer's order for turn-on of a new service, when closing bill at previous address has not been paid? Action taken would depend largely upon circumstances. If there was sickness, or some other good reason why service should not be denied, we attempt to get a payment "on account," balance to be paid in a few days, making it understood that the future date or dates of payment must be lived up to, and order the service turned on.

If a consumer out of work or sick, asks you to grant free water, what is your answer? The consumer is courteously informed that he should contact the district visitor of the County Welfare Department, or a local recognized charitable institution in regard to free water service, as our water department grants such service only at the request of the Social Service Department.

Suppose the owner of rented property requested water service discontinued and equipment removed from his property, in order to force tenants to vacate, what would you do? The owner would be informed that we can turn service off if he so wishes, but the tenant can make application for service there in his own name, and service will be connected providing the tenant conforms with our rules. We cannot remove equipment except on delinquent accounts.

Suppose a consumer questions the accuracy of his meter? Upon request of consumer, we will make an official test at the Department's expense. The consumer is notified of the time and place of test and may be present if he so desires. The meter is taken out and a new one set; and the meter in question is tested at variable rates of delivery at our meter shop. If average registration is found to be more than 2 per cent in excess of actual quantity of water passing through the meter, it will not be re-set; and the consumer will receive credit for the approximate overcharge for the period claimed—but in no event for more than six months.

How do you handle a consumer who resents paying for a meter that has been damaged by hot water or steam from his premises? We make no charge for the first offense for burned meter; but the consumer is informed at that time that should there be a recurrence within the next three years, he will pay the cost of changing and repairing this substitute meter. We show him the disk that has been warped by hot water backing up in the pipes and through the meter to the water main, through consumer's carelessness or faulty plumbing equipment.

When charges on a burned meter must be collected, and the service is in the name of the property owner, what could you do for him if he requested that you collect from the tenant responsible for the damage? If the owner has signed for the service, he, of course is responsible for the charges. However, if he wishes, we will mail a duplicate bill, in the owner's name, to the tenant.

Does your department require a residential consumer to make a deposit to guarantee payment of water bills? No, not when the consumer can furnish satisfactory credit information at time application

is made. However, if later the account shows that the consumer has been delinquent in payment of his bill, his account is symbolized; and if the delinquencies continue, he is served with a notice that he will be required to make a cash deposit to guarantee all future water bills, or service will be discontinued.

If a former delinquent consumer becomes prompt in his payments, may he ask that his cash guarantee deposit be refunded to him after eighteen months continuous satisfactory payment of bills? I would explain that the cash deposit is made to guarantee payment of bills and that it is not customary to refund such a deposit except upon discontinuance of service; but deposit may be refunded if the consumer can establish satisfactory credit.

Do you find that consumers resent giving credit information? Very seldom, after we explain our reasons for requesting the information, and that if satisfactory credit is not established, it will be necessary for us to request a cash deposit equal to double the estimated bill.

Do you pay interest on these deposits? No. All money taken on deposits is turned over to the City Treasurer subject to our call at any time. We derive no interest or benefits from the deposits, so we are unable to pay interest. This procedure is governed by our city charter.

How do you handle high water bills resulting from underground leaks? Where an inspection of the property shows that the leak is in no way caused by the consumer's negligence, and that he is not aware of the fact that the leak is taking place, adjustment is made on a fifty-fifty basis.

Why did you discontinue house to house collections on water bills? The principal reason was the much lower cost of mailing the statements, when compared with the salary and transportation costs for field collectors. Then too, very often the collectors found no one at home; some consumers objected to collectors calling; and in the greater number of cases, the consumers were not prepared to make payment when the collector called. Our records show that 60 per cent of our bills are paid through the mails; and the same close follow-up on delinquent accounts is necessary whether original bills are mailed, or presented in person.

Who pays for the installation of fire hydrants, and who maintains them? We install all fire hydrants, but the sizes and locations must be approved by the Fire Department. In new subdivisions, the tract or property owner pays the cost of installing; but the installa-

tion cost of fire hydrants to be supplied from water mains already installed, is borne by the Fire Department. The Fire Department pays us a flat rate of $3.00 per month per hydrant for maintenance and service.

What is your practice when a consumer requests that a fire hydrant be moved? We move fire hydrants short distances when requested, providing the consumer making the request pays all expenses in connection with the relocation, and can obtain permission from the Fire Department for this location change.

Why do you insist that applicants for new water service furnish the legal description of the property as well as the house number? Because the legal description definitely determines the property on which the connection is to be installed, thus eliminating the possibility of our installing the service on the wrong lot, with consequent financial loss to the applicant. And, too, the fact that the water service connection is sold to the property and not to the house, is important if and when this property is later on subdivided—when the service is considered as belonging to the lot or parcel it directly enters.

Why are your water rates higher outside the corporate limits of the city than inside? The installation of our water system was comparatively expensive as the greater portion of our water is brought a distance of approximately 328 miles before entering our mains; and the original cost of $26,500,000 for this aqueduct was paid by the citizens who were taxed for bonds to cover this construction cost; and it would be an injustice to them to sell water outside the city for the rate paid by those within the city limits, when these outside consumers had not participated in the cost. The consumers outside the city get the benefit of this original cost, so they should pay a higher water rate; and, too, the cost of maintenance and distribution outside the city is usually higher, because of the difficulty in protecting mains along unpaved and ungraded streets and highways.

Do you make any exceptions to this higher rate outside the city limits? Yes, to the United States Government. Water used within the buildings of federal institutions engaged in caring for disabled, honorably discharged veterans of the United States Army, Navy, and Marine Corps, is charged at our regular city domestic rate. Water used on the grounds is separately metered and charged at our city rate for parks and playgrounds. A recent amendment to our existing

water rate ordinance for consumers outside the city limits grants this same city domestic rate for water used within buildings erected as County Housing Projects.

If you annex outside territory, do you buy their water systems? We have no funds available for the purchase of private water systems; and it would be very seldom that an annexed territory would have a distribution system that would meet our specifications—and withstand the pressure maintained in our distribution mains.

What is your procedure when a consumer insists that the water pressure is too high? We install, at the consumer's expense, a pressure regulator, strainer, and relief valve, and regulate the pressure to suit the customer. These regulators will be inspected and tested by our department upon consumer's request; but if any repairs are needed, this cost must be paid by the consumer.

What is your practice when property is located at such an elevation that it is impossible to furnish an adequate water supply at all times? Our service elevations range to 1,720 feet, and we have reservoirs and tanks so located that we try to give satisfactory service to all applicants; but if the property to be served is less than 100 feet lower than the reservoir supplying the property, the applicant is required to sign an elevation agreement (to be legally recorded) relieving us of responsibility for adequate service during peak periods when pressure might be low. Should a low pressure condition develop, we request the consumer to install a pump and pressure system in order that adequate pressure may be maintained.

Have you any special practices for stimulating interest in your water department and strengthening the cooperative spirit of your consumers? Yes, for we find that the better the public is informed on what we are trying to accomplish, the more whole-hearted their support.

Educational Activities

Here is one particularly interesting practice: upon request we arrange for field trips for various groups such as clubs, civic organizations, and schools (teachers and/or pupils). An employee of our department conducts the group over a portion of the water system, explaining the source of our water supply, and how the water is transported to the city, stored, chlorinated, distributed, etc. Then

for larger groups, dinner meetings, engineering societies, etc., our engineers give talks on the water system, and the talk is illustrated by either colored slides or moving pictures.

Just now we are issuing each month a small leaflet giving timely advice on planting, soil preparation, and care required by various plants, shrubs, and trees. We enclose this leaflet with our water bills and it has stimulated public interest in gardening to a surprising degree; and civic pride has caused our consumers to beautify not only their home gardens, but some adjoining vacant lots as well. The material for the leaflet is furnished by our local horticulturists, and edited by one of our employees; and the printing cost is less than one half cent per copy. (See Jour. A.W.W.A., **31:** 109 (1939).)

These activities may seem unimportant and unnecessary to the business of selling water, but we feel that we are community builders and developers as well as water distributors; and if we can cultivate such a cooperative relationship with our consumers that we can all work together for a greater common good, we will have accomplished something well worth while.

Potential Health Hazards in Distribution of Water

By Arthur E. Gorman

IN CONSIDERING the sanitary quality and safety of a public water supply, it is the product as delivered at the consumer's tap which is the mark of real service to the community. In supplying water, as in the merchandizing of any other commodity to the public, there are four major units of service which must be under continuous control by a competent organization to meet the needs of the consumers. These are: first, an adequate and suitable source of supply of the raw product; second, an effective means of processing the product for public consumption; third, an adequate reserve supply of the finished product to meet variations in consumer demands; and fourth, proper retail outlets to the ultimate consumer. In accepted merchandizing terms these four services may be classified as: supply, processing, warehousing and distribution.

In general, public health and water works officials have seen to it that the first three of these services are reasonably well provided for. It is the purpose of this paper to direct attention to certain weaknesses in our system of distributing or retailing water, particularly as they may concern the public health.

Because of the public health importance, great emphasis has been placed and much money has been spent in obtaining water from adequate and suitable sources of supply. Sanitary police and high fences are now used to safeguard watersheds from pollution; strict regulations are enforced to control the degree of pollution of water courses—both surface and underground—which are used as sources of public water supplies; technically trained operators are employed to control the processes for purification and other treatment of the supply; and specially constructed storage reservoirs are

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built to safeguard the purified product from after-contamination. All of these services are provided to the end that a clean, safe and palatable water may be supplied to the public.

Sources, Treatment and Storing Are Satisfactory

Generally speaking, in the supplying, processing and warehousing of our commodity, we water works and public health officials are doing a reasonably good job measured by recognized standards. We are, for the most part, proud of the results of our production and control measures as indicated by the condition of the water sent from our plants to the storage reservoirs or water warehouses. We are pleased to point to the laboratory records showing zero entries for gas formation in fermentation tubes used for testing for coliform organisms in the treated water; if we have a moderately new plant, we may even demonstrate the crystal clearness of our product by letting visitors look down into a sight tube to see, through ten or fifteen feet of treated water, the seal of our city or water department inlaid in contrasting colors against a clear white background on the bottom of the storage reservoir. Our school children, our daily press and of course our Chamber of Commerce may hail to the world the purity of our local water supply; it is probable that the state board of health will certify our supply for use on interstate carriers, basing its decision on the systematic reports of plant operation. In short, we are all proud of our water supply system—at least that part of it which we can see. But what of the underground distribution system which cannot be seen?

Returning to our commercial analogy, in merchandizing any commodity it is the quality of the packaged product as used by the individual consumer which measures the success of the firm or enterprise marketing that product. It is of little avail commercially to produce and warehouse a fine quality merchandise, if it is permitted to deteriorate or to become damaged through retail outlets. In water works the retailing outlet is the distribution system and the packaged product is the water which flows from the consumers tap. This is the water with which the individual consumer must be satisfied; this is the water he is billed for regularly. Therefore, this is the water to which our standards of quality should logically be applied.

Our wholesale distribution system is composed of underground tunnels, conduits or feeder mains wholly out of sight and too often

out of mind until trouble develops; our retail routing is through smaller mains and services leading ultimately to more or less concealed piping on the consumer's premises. In this latter connection, let us not forget that every plumbing fixture has both an inlet from the water supply system and an outlet drain to the sewer.

It is the writer's opinion, based on many years of experience in water safety control measures, that there are, in every water works system and especially in those of large cities, more potential pollutional hazards than are generally realized by water works and health officials. Many of these hazards are intermittently operative to cause local pollution of the water supply which is never detected because the results are not dramatic and illnesses which may develop are not reported. It is difficult to produce factual evidence in the way of official statistics to support this belief, because of lax reporting of cases. Witness, for example, the experience in the wave of influenza, a reportable disease, which swept over the country last winter. Official reporting gave no satisfactory clue to the widespread extent of illnesses which occurrred, yet in many public schools the absences of teachers and pupils were exceptionally numerous.

Potential Dangers and Actual Outbreaks

The element of chance between potentiality and actuality in events which affect our daily lives is often very thin indeed. But with each exposure to risk there is an accident ratio depending on circumstances. It should be remembered, however, that errors or accidents which cause a public water supply to become polluted are especially hazardous and may result in a major catastrophe in the community, such as the water-borne epidemics at Salem, Ohio, in 1920; Cochrane, Ontario, in 1923; and Santa Ana, California, in 1924.

The typhoid fever death rate of a community is still accepted by too many health and water works officials as an index of the safety of the public water supply, although the present paucity of typhoid fever cases in most communities makes this index of doubtful value except in times of special outbreaks. Diarrheal disorders, if properly reported, might be a better index. Unfortunately there exists a certain tolerance of physical upsets of this kind which is usually associated with neglect in the calling of a physician and even if this were done, there is now no assurance that the case would be reported officially.

Health and water works officials should co-operate to stimulate

prompt and accurate reporting of all diarrheal disturbances in their communities and should be prepared to follow up with adequate epidemiological, engineering, and laboratory investigations. They would, I feel sure, be surprised at some of their findings, instead of being complacent because of their ignorance of facts. The time has come when water works and health officials should give more attention to the distribution of water in public systems and more support to operating officials in charge of the distribution system in extending, repairing and inspecting their systems.

The distribution system of public water works deserves better recognition for its value in service to consumers and because of its potential health hazards in the retailing of water. Literally, it is the great hidden asset of every water works; its material value may represent the largest group investment in the system; it must serve continuously year in and year out. But still it is altogether too often the "forgotten man" of the system in its initial installation, subsequent extensions and repairs, and in general inspection and control. This situation is wrong and should be corrected.

Axioms for Prevention of Health Hazards

To prevent health hazards in the distribution of water three conditions are almost axiomatic:

1. Maintain as tight a system as possible.
2. Keep pressure on the system at all times.
3. Guard the system against pollution from consumer premises.

To maintain a tight system and constant pressure requires proper design, good installation, intelligent operation, careful inspection, adequate maintenance, and proper technical supervision. These are definitely the responsibilities of the water department and the health hazards to water consumers are likely to be in direct proportion to the thoroughness with which they are met. Loss of pressure in a water system, with underground leaks, constitutes a very serious health problem which must be given a great deal more attention by both water works and health officials.

Guarding public water systems against pollution from consumers premises has its difficulties, but the responsibility of the water department cannot be dodged on the grounds that what the consumer does with the water after it passes the meter is the customer's business.

As a public health precaution the water works official should know

the uses for which water is purchased by each of his consumers. Where this use involves a pollutional hazard, such as possible cross-connections with a secondary system or the preparation of hazardous chemical solutions, proper care should be taken to protect adjacent consumers from the possibility of pollution of the public system through service to premises where water supply hazards exist. Areas where sanitary sewers are subject to flooding, premises located along polluted waterways, and hilly sections where low pressures may prevail are all especially subject to pollutional hazards to the water distribution system.

Theoretically, water service is in one direction—from the public system to the consumer. However, when pressures drop, when water mains are drained for repairs, or when water is repumped to elevated storage tanks, a reversal of flow may take place. Such occurrences may be more frequent than is generally realized.

Milk Handling Precautions Compared

Health officials insist that for the protection of other consumers, milk dealers who supply dairy products to homes under quarantine, take unusual precautionary measures. Isolation of bottles from those in general use and special sterilization of containers received from the customer are usually required. Why should not water works officials institute equivalent safeguards to public water systems to prevent their being polluted by possible reversals of flow from premises maintaining pollutional hazards likely to involve public supply? The writer believes the public supply to premises maintaining such hazards should always be delivered to a receiving reservoir or so-called surge tank, so constructed and fitted for service, that under no circumstances could secondary water supplies be returned to the public system. If necessary, the customer should be required to repump all water supplied by the public system.

Pollutional hazards in a water distribution system may arise from errors in design, installation and operation of that system as well as from hazards on consumers' premises. In the former instance, there rests a definite responsibility on the water works management. With reference to hazards on consumer premises there may be a divided responsibility, but in the writer's opinion it is incumbent on every water works management to investigate possible hazards on consumers' premises before service is rendered and to supply water under conditions which will definitely protect all other consumers

served by the water system and minimize, at least, pollutional hazards which the customer's operations might bring about.

Policies of Other Utilities on Consumer's Premises

Other public utilities are very careful about the installation and use of their service facilities and equipment on consumer premises—why should not water works officials adopt the same policy? As a public relations policy, as well as in the interest of public health, water departments should render special technical service and advice to water consumers who have unusual and possibly hazardous operations with which to contend. There is room for much more cooperation of this type between water utility operators and their customers.

It goes without saying that every water works should make periodic inspections of the water system or systems on consumer premises where hazards are likely to exist, as a protection of the public system against illegal cross-connection. Capable inspectors can do much to educate plant and building operating and maintenance officials in eliminating pollutional hazards of all kinds.

The recent decision of the Supreme Court of Massachusetts[1] in finding the town of North Attleboro responsible for the quality of water supplied to a consumer through a long lead service pipe, thus causing lead poisoning, is an indication of a new legal attitude toward the responsibility of water utility operators in supplying satisfactory water to their customers. The law of implied warranties has many possibilities of involving water departments in expensive litigation and this court finding in Massachusetts gives much weight to the importance of measuring the degree of water service and quality by that rendered at the consumer's tap.

Hazards in Design

In the design of a distribution system, particularly in hilly regions, special attention should be given to maintaining adequate pressures on the system at all times. Every precaution should be taken to prevent draw-downs which will result in the creation of negative head in the distribution system, either in periods of abnormal usage or during shut-downs for repairs. Reservoirs floating on the system, adequate sizing of mains and proper location of valves to permit

[1] Chase, E. Sherman. Purveyor Held Responsible for Water Quality on Customer's Premises. W. W. and Sew., **18:** 154 (1929).

localizing of shut-downs for repairs to limited areas will do much to avoid negative head difficulties in the system. The writer firmly believes that designers should be liberal in specifying recording compound vacuum-pressure gages at critical high points in water systems, so that the true story of service pressures under all conditions of operation may be known. When high and low pressure systems are designed, special attention should be given to the maintenance of proper pressures in the outer fringe of each zone. Every section of the water system should be served by at least two feeder mains, so that an interruption in supply from one will not result in a complete loss of pressure in the area affected.

Installation Hazards

Carelessness in handling pipe on the job is altogether too common in water works construction. Much educational work should be done in the interest of public health in pointing out to contractors pollutional risks pertaining to their work in installing water mains and accessories. A good set of specifications should include items relating to the prevention of pollution of the system during construction.

Setting pipe along gutters and at low points, where it may become contaminated by trench darinage water or even the overflow from nearby sewers, should be avoided. A practice of setting pipe on blocks or some other resting piece off the ground would eliminate much unnecessary exposure of new pipe to pollution. It would also make final sterilization of the main by chlorine compounds and cleansing by flushing much more effective.

There is room for much improvement in the care in handling pipe while being set in position in the trench. Joint packing material is often exposed to serious and unnecessary contamination by careless storage and handling by the contractor's employees. A rubber tube joint packing recently put on the market has much to commend it because of the ease with which it may be handled and sterilized to prevent contamination.

The relative location of water mains to sewers or house drains is an important health matter and is a factor deserving of much more consideration than it now receives. A leak in a main or service connection near a sewer or house drain, may go undetected for years especially in an unmetered system. Should these pipes be drained or a negative head be developed in the water system, sewage might easily pollute the water supply.

The writer has seen water mains passing directly through a public sewer, the latter utility having been installed by a contractor without the knowledge of the water department. A water pipe and sewer in close proximity to each other in an area subject to vibration due to heavy trucking, the passing of trains, or the unloading of heavy supplies is a very dangerous condition. Mains laid too close to the surface are subject to strain at the joints due to frost action on the surrounding soil. The smashing of pavement surfaces by dropping heavy iron balls and the use of steam shovels in clearing away paving material may seriously injure water mains laid close to the surface. Broken feeder mains can do untold property damage in the vicinity of breaks because of leakage into basements, the submergence of merchandise and operating equipment in buildings, the wash-out of utilities and breaking of connections to empty or partly empty tanks, due to extraordinary buoyant forces. Paving slabs can be heaved due to the upward force of the water over a large area.

All accidents resulting in main breaks are a threat to the public health because sewage may leak into the pipes or the resultant draw-down of water in riser pipes in buildings may cause a negative head in the system with back siphonage of fixtures and a flow-back of polluted water into the water mains through the service connections.

The use of material in water mains which is unsuitable to the ground through which they are laid may result in corrosion with subsequent leakage and related hazards. Improper grounding of electrical circuits may cause stray currents to attack water mains and corrode the pipe.

Failure to consider regional metereological extremes in designing and installing water mains may result in accidents which could have been avoided. The influence of freezing has already been mentioned. Excessive rainfall or extraordinary tides, earthquakes or land slides may cause wash-outs or subject mains to unforeseen strains on the joints, with resulting leaks.

Submerged river crossings are always points of potential leak hazards. Even if the pipe be laid on saddles in a tunnel under the river the special fittings necessary to turn the pipe downward or upward at land shafts on either end of the tunnel are subject to unusual strain at the joints.

The direct connecting of the weep line from fire hydrants to sewers is, in the writer's opinion, a definite risk to the water system. Should the hydrant valve be left partially open, such an installation may

permit a cross-connection to be established between the sewer and the fire hydrant. If a negative head were to develop in the water mains while sewage from a surcharged sewer was standing in the hydrant riser, pollution could be drawn back into the water mains. Similarly drains to sewers from valve and blow-off basins and fire cisterns could be the means of contaminating the water system. The old-fashioned driven corporation cock for service connections frequently becomes loose and causes points of leakage through which contamination could enter the main.

Hazards in Operation

When pressure is shut off or lowered on a water system, even for a few seconds, hazards of all types are greatly multiplied. The most important maxim which can be followed by those in charge of the operation of a water system is to keep pressure on the system at all times. Obviously this cannot be done in all sections of the system because repairs, replacements, extensions and tests must me made, and unforeseen accidents will happen. Shutdowns for maintenance and test purposes should be minimized in number and the length of time that service is curtailed. They should never be made without proper authorization by some official in authority who has full knowledge of the effect of this shut-down locally and on the entire system. Consumers should always be forewarned of shut-downs in water service giving them an estimate, if possible, of the time and duration of the period of interrupted service. When emergencies of this kind develop in an area where secondary sources of supply are conveniently available, the consumer should be warned against making temporary cross-connections which may be dangerous. Every effort should be made to keep as much water as possible in the main which is shut down, to minimize the opportunity for outside contamination to enter. Proper planning of many repair jobs would permit hazards of such shut-downs to be materially lessened.

Loss of pressure in a water distribution system due to accidents such as a main break, interruption of power to pumping engines or the closing through error of a valve in a large feeder main, especially in a section not supplied by auxiliary feeder mains, may have serious public health consequences. This is particularly true if the area affected is on high ground, because the draw-down of water from the crest of the system could cause a negative head to develop in certain sections. Such a condition would permit pollution to be sucked

back into the mains or services wherever underground leaks existed, as well as back siphonage of improperly constructed plumbing fixtures, particularly those with submerged water inlets. It is because of such possibilities that the placing of water pipes and service connections in the same trench with sewers and house drains is bad practice.

The suddenness of accidents involving loss of pressure in a system makes preventive measures difficult, because the period of negative head may be very short and in the eagerness to restore water service to consumers, sanitary control measures may not be fully complied with. When pollution reaches the distribution pipes of a water system, it is very difficult to cope with and in certain sections where circulation in the system is not good, contamination may persist for a long time.

In water works supplied with unfiltered water, there may be considerable sediment in those mains where velocities are low. Bacterial aftergrowths and high chlorine demand are likely characteristics of water in such mains. Similar conditions may be found in the zone of sluggish flow along the boundary between adjacent pumping districts. When for one reason or other, such as the opening of a previously closed valve or a greater flow of water due to some unusual local demand as in case of a fire, a higher velocity occurs in such mains, this sediment may be carried along with the water and cause many consumer complaints. To what degree this objectionable condition is a health hazard is uncertain, but reports of illness frequently follow complaints of dirty water by consumers.

In recent years, due to federal work projects, an abnormal amount of rehabilitation and repair work has been done on the distribution systems of public water works. It has been the writer's observation that consumer complaints come most frequently from areas where such work is in progress. There is a risk in permitting field repair gangs to close valves in a water system. This work should be carefully supervised by a responsible employee familiar with the distribution system and properly informed of field conditions, by having accurate plats at hand and not directing operations from memory. For the protection of the water department against the consequences of mistakes in the closing of valves, it would be prudent to require each foreman or engineer to submit daily a report on each closure, which record should be carefully filed.

When new services are to be installed and a tapper is sent out, he

should have specific information concerning the service location, the supply main, and all utilities in the vicinity of the job. If this were done, such accidents as tapping gas mains or high pressure pipes carrying polluted or poisonous fluids could be avoided. Where mains of this character are laid under city streets, special precautions should be taken to see that they are not mistaken for water pipes. By all means they should be shown on all pipe plats by a distinctive warning color.

Systematic training of employees concerned with the operation and maintenance of water distribution systems would do much to minimize all types of hazards. In particular, employees should be instructed in the elementary precautionary measures necessary to protect the public health. There should be a close liaison between the division responsible for water distribution and all other operating divisions, so that irregularities in the operation of the system may be taken care of, if possible, in the distribution of water to consumers.

Hazards on Consumer's Premises

The various types of cross-connections which may exist on consumer premises between the public water system and secondary water systems are too numerous to enumerate here. They have been discussed at great length in other papers presented before this association.

It should be remembered, however, that the flow of water through service pipes is not always in one direction and that there may be occasions when the flow is backward from the consumer's premises into the city system. The greatest hazard occurs when there is a shut-down of pressure in the public system due to an accident or to the necessity for repairs. Then, any polluted or poisonous water stored or used on the consumers premises which is connected either directly or indirectly through faulty fixtures to the supply from the public system may flow back into the street mains.

Periodic shutting down or draining of water systems or parts of systems on consumers property may so contaminate that system that in case of a shut-down or break of a water main in the street, local contamination of the public system might result. In a large public institution under investigation by the writer because illnesses had been reported, it was found to be the practice to drain the water system each Friday night in winter to eliminate the necessity of heating the building to prevent freezing of pipes and possible damage

due to vandalism. A recording pressure gage registered a 16-inch vacuum in the upper story of the building shortly after the main drain in the building water system was opened. Marked siphonage of toilet fixtures into drinking fountains was proven by dye tests.

Siamese connections on large buildings to permit fire department pumpers to deliver high pressure water to the fire main and sprinkler system within are potentially dangerous when these buildings are located along polluted waterways into which fire engines or fire boats may drop their suction hose. In many of these cases, it would be possible for the high pressure in the fire system to force water back into the city mains through the service connection to the building, even though check valves had been installed.

Danger in Repumping

Where water is repumped in a building and the pump has a capacity out of proportion to the size of the service connection, it is probable that every time the pump is put into service a negative head will be created on the suction side. Any local water lines for low pressure service which are taken off the supply pipe between the pump and the service from the city would be intermittently subject to negative pressure.

Large fire pumps in industrial areas may seriously affect water pressures in a public system, unless the supply mains are properly sized to meet this demand. Such pumps when automatically controlled to supply water to the general system of a plant when pressures from the public system are low are particularly dangerous. In case of reduced pressures in the public system or an interruption of service due to accidents, these pumps would automatically start and for a period could cause a serious negative head in the public system over a wide area.

To protect certain unheated areas served by automatic sprinkler systems, fire insurance officials require the use of non-freezing solutions in the exposed sections of the sprinkler piping. Some of these solutions such as carbon tetrachloride and certain ethylene compounds may be toxic and back-siphonage might cause them to be drawn into the local water system.

Submerged service inlets to storage tanks, vats, reservoirs, and other water containers should be prohibited because of the possibility of back-siphoning into the city system.

Conclusion

In conclusion, the writer recognizes the fact that it may not be possible to eliminate all of the many types of potential health hazards which have been discussed in this paper, and he wishes freely to admit that the listing herein is quite incomplete. But it does seem that the time has come for water works and health officials to give more consideration to what happens to the water in public systems enroute to the consumer and to endeavor systematically to minimize potential health hazards which now exist. In the meantime, it might be prudent as a public health measure to consider increasing the factors of safety in the distribution of water by carrying sufficient residual chlorine in the supply to consumers to give protection without risk of complaints. Personally the writer believes that there should be some residual chlorine in every drop of water as it flows from the outlets on the premises of all consumers.

Bacterial Pollution of the Niagara River

Part 1. Conditions Before Sewage Treatment at Buffalo, N. Y.

By G. E. Symons and R. W. Simpson

THE Niagara River is unique in many respects. It is only 36 miles long and yet in that 36 miles it manages to fall 326 feet, most of which is a drop over a falls that is one of the scenic wonders of the world. In this river lies one of the largest islands in the world surrounded by fresh water. It takes less than a day to run its full length although 185,000 to 200,000 cubic feet of water pass down it every second. It lies between two countries that have been at peace for 126 years, but within its turbulent self a ceaseless war has raged between its normal inhabitants and the tremendous numbers of bacteria that have until recently been poured into it.

The first studies made on the bacterial pollution of the Niagara River were carried out by the State Department of Health on November 7, and December 4, 1907. This agency repeated the survey on April 28 and 29, 1913, and again on August 4, 1931. During this period there was, of course, a large increase in bacterial population reflecting the growth of the city of Buffalo.

The Department of Health reports indicated that the pollution followed the New York shore all the way to Niagara Falls. The reports also gave a key to the proper test dilutions at the different locations, and indicated the proper locations for sampling stations. With this information available, the need for much preliminary work in recent studies was eliminated.

Since June, 1936, the Bird Island Laboratory, of the Buffalo Sewer Authority, has made regular monthly surveys of the river,

A paper presented on May 30, 1939, at the New York Section meeting at Rochester, N. Y., by G. E. Symons, Chief Chemist, Buffalo Sewer Authority; and by R. W. Simpson, Associate Sanitary Chemist, Buffalo Sewer Authority. This paper is Part 1 of the study. Part 2 will discuss the results achieved by sewage treatment at Buffalo and will be published within the next year.

collecting some 40 samples in the warm months and 17 samples in the winter months. Monthly surveys were also made of the Buffalo River, a small tributary, and a few studies were made at Niagara Falls. This report summarizes the first 25 months of study on the Niagara River, covering the period immediately preceding the inauguration of sewage treatment at Buffalo, New York. Part 2 of this report, showing the effect of sewage treatment on the bacterial pollution of the Niagara River, will be prepared after the first year of sewage treatment at Buffalo has been completed.

Method of Study

In fig. 1 are shown the locations of the various sampling stations, not only on the Niagara River but also on the Buffalo River. The designation of the series of stations follows that adopted by the Department of Health. This map also shows the pollution boundary line which will be discussed later.

The Department of Health reports showed that the pollution from the American shore did not mix with the entire flow of the river and therefore it was apparent that some measure of the flow in different cross-sections was essential. Accordingly, Greeley & Hansen, Engineers for the Sewer Authority, made current meter and sounding observations at both Series E and EE locations. The division of waters between the Tonawanda (American) and Chippewa (Candian) channels was calculated from these current meter studies to be 43.3 per cent for the American Channel and 56.7 per cent for the Canadian Channel. The total discharge of Lake Erie into the Niagara River could be calculated from the Lake Level Survey formula, as follows:

$$Q = 3883\ (B-558.37)^{\frac{3}{2}}$$

where Q is the discharge in c.f.s. and B is the mean Buffalo lake level gage reading. From these data were calculated the Quantity Units of coliform according to the formula:

$$\text{Quantity Units} = \frac{\text{c.f.s.} \times \text{coliform/ml.}}{1000}$$

thereby giving a weighted value to the data at Series E and EE.

During the warm weather months, the surveys were made by a boat furnished and run by the Department of Conservation. In the winter, samples could be taken only from the Grand Island Bridges and, at times, shore ice prevented the collection of the entire series of samples at these locations.

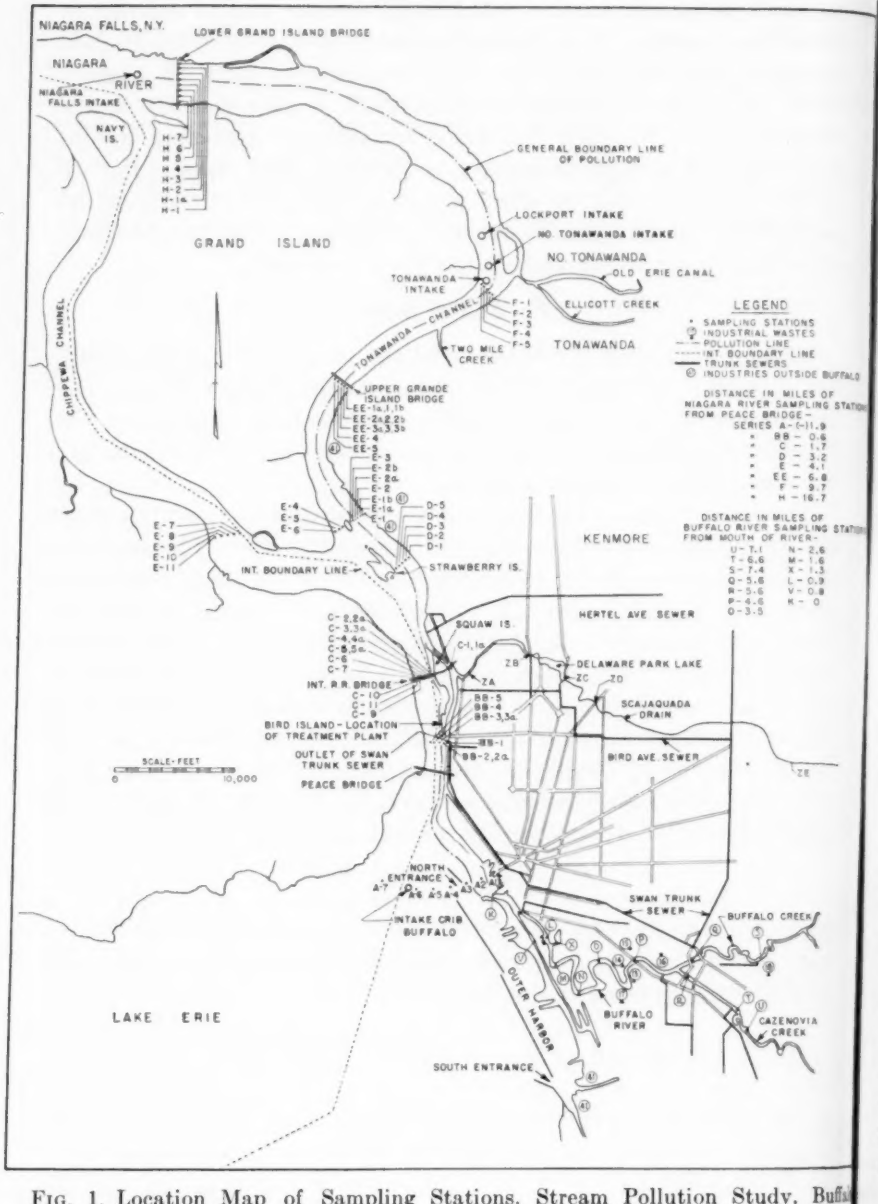

FIG. 1. Location Map of Sampling Stations, Stream Pollution Study, Buffa
Sewer Authority, 1936-38.

All samples were collected in a depth sampler containing a sterile bottle. The tube through which the sample entered the bottle was also sterile, a different tube being used for each sample. Samples were collected at depths of 6 to 8 feet below the surface. There is so much "boil" and overturning of the water in the Niagara River that there is little likelihood of stratification or uneven distribution of the pollution from top to bottom.

Shortly after the collection of each series of samples, the boat was met by truck and the samples taken back to the laboratory. The time for collection of each series of samples was regulated so that it approximated the flow time of the river to that point. Table 1 shows the distance of the sampling stations from the Peace Bridge

TABLE 1

Location of Sampling Stations in Niagara River Surveys

SERIES	LOCATION	MILES BELOW PEACE BRIDGE	FLOW TIME FROM PEACE BRIDGE
A	Water intake Crib	−1.9	
BB	Ferry Dock	0.6	0 hr. 10 min.
C	International R. R. bridge	1.7	0 hr. 25 min.
D	Strawberry Island	3.2	1 hr. 25 min.
E	Motor Island	4.1	1 hr. 45 min.
EE	Upper Grand Island bridge	6.8	3 hr. 45 min.
F	Tonawanda Intake	9.7	6 hr. 0 min.
H	Lower Grand Island bridge	16.7	11 hr. 40 min.
HH	Niagara Falls intake	17.1	12 hr.

(i.e., the beginning of the river) and the approximate flow time to each point for a flow of approximately 185,000 cubic feet per second. These latter data are from curves prepared by Greeley & Hansen, Engineers.

Except for the last series (H), the samples represented, fairly well, the same water and pollution. Not only did the time element interfere with the sample at Niagara Falls (Lower Grand Island Bridge), but sewage and trade wastes along the river also have an effect. Perhaps, then, the data at Series H are not exactly comparable to the other data, but they are comparable within themselves from month to month.

In the laboratory, the samples were cultured immediately on arrival. The most probable number of bacteria of the coli-aerogenes group (herein called M. P. N. of coliform) was determined by serial

dilution in lactose broth using 3 or 5 tubes. Confirmations were not made. The total bacteria per ml. were determined on Agar at 37 C. The coliform M. P. N. are reported per milliliter in this paper. For the most part, the total count is not reported here since it is of less significance in the studies.

In addition to the monthly surveys, daily data at Niagara Falls were obtained, and four 24-hour studies were made of the raw water at the Niagara Falls filtration plant. Laboratory studies were also made to determine the effect of dilution on the bacterial population of both raw and chlorinated sewage. These various correlated studies will be discussed later.

Extent of Pollution in Lake Erie

The 1936 surveys showed relatively no pollution in Lake Erie outside of the Buffalo Harbor and similar conditions in the Canadian channel around Grand Island, and the small channel between Grand Island and Motor Island. This is shown by the data in table 2.

Station E-11 shows the effect of pollution from Fort Erie, Canada. These data indicate that the lake water that passes down the Canadian channel is unaffected by Buffalo pollution. Collection of samples at all of these stations was discontinued in 1937 in order to concentrate sampling in the polluted American channel.

Source of Pollution in Niagara River

Before presenting the actual data collected from these studies, it is well to discuss the source and the conditions of pollution of the Niagara River. In 1936 it was estimated that on a volume of waste basis, Buffalo contributed approximately 83 per cent of the pollution originating in the Niagara Frontier. Niagara Falls contributed approximately 10 per cent and approximately 5 per cent of the total was contributed by towns and industries located between the two cities.

Prior to the construction of intercepting sewers in Buffalo, the sewage was discharged at several points and this fact, undoubtedly, had an effect on the bacterial content below Buffalo. The dry weather flow from Buffalo is approximately 160 c.f.s. Of this, approximately 45 per cent entered the river directly from the Swan Trunk Sewer (fig. 1), a short distance below the Peace Bridge (i.e. at Station BB) and 15 per cent (Hertel Ave. Sewer, fig. 1) entered the river directly some distance below the International Railroad Bridge. Twenty-five per cent of the flow entered the Black Rock Canal

above the locks (see fig. I, Bird Ave. Sewer). Sedimentation and digestion of sewage solids created a septic condition in the canal and an increase in bacterial content. The flow out of this canal, by way of the old Erie Canal, was only four times the sewage flow and this septic water, with its high coliform content, entered the river at the same place as the Hertel Avenue Sewer (fig. 1).

The remaining 15 per cent of the sewage entered the Buffalo River. This is a dredged stream forming a part of the Buffalo Harbor. Because the flow is small, the detention period is long and this coupled with heavy industrial wastes created a quite septic condition with a large increase in bacterial numbers.

Thus, the Niagara River was receiving approximately 60 c.f.s. of raw, relatively fresh sewage, the coliform content of which ran

TABLE 2

Six Months Average (1936) Cross-Section Bacterial Contents in Lake and Canadian Channel

STATIONS INCLUDED IN CROSS SECTION AVERAGE	LOCATION	AVG. BACTERIAL CONTENT JUNE TO NOVEMBER INCLUSIVE	
		Total Count per ml.	Coliform per ml.
A-3,4,5,6,7	Opposite Buffalo Harbor Entrance	170	0.30
E-4,5,6	Motor Island Channel	50	0.44
E-7,8,9,10	Canadian Channel	33	0.36
E-11	Canadian Shore Water	111	26.2

from 50,000 to 300,000 per ml. and approximately 200 c.f.s. of septic, badly polluted water with a coliform content of from 10,000 to 20,000 per ml.

From the studies reported here, it was calculated that pollution from Buffalo was never dispersed in more than 30 per cent of the total flow of the Niagara. On this basis, the dilution factor for Buffalo sewage was approximately 1 to 320. Or, if the dilution factor were calculated for the sewage plus septic stream flow, it would be approximately 1 to 200.

Thus it is fairly obvious, from a consideration of these dilution factors, that nuisance or septic conditions in the Niagara River were not likely, but it is also obvious that under these conditions the bacterial content of the river would be greatly affected. The data given in tables throughout the remainder of this paper will show this effect.

Bacterial Data

For purposes of simplifying the presentation of the data for each series (i.e. cross-section) the base data are averaged for each month and shown in table 3.

TABLE 3

Average Bacterial Concentration per ml. at Each Series of Sampling Stations

	COLIFORM/ML.						TOTAL BACTERIAL COUNT/ML.					
Series.....	BB	C	D	E	EE	H	BB	C	D	E	EE	H
Miles below Peace Bridge..	0.6	1.7	3.2	4.1	6.8	16.7	0.6	1.7	3.2	4.1	6.8	16.7
Flow Time...	0:10	0:25	1:25	1:45	3:45	11:40	0:10	0:25	1:25	1:45	3:45	11:40
1936												
June..				127	230	39.9				330	570	615
July....				466	295	45.3				2420	3840	820
Aug....				161	470	42.1				1650	1000	140
Sept....				207	890	71.4				7770	10,900	1530
Oct.....				820	1680	127.0				924	1850	220
Nov....				30	180	165.0				2310	2400	730
Dec....				—	120	96.7				—	1420	175
1937												
Jan.....					180	222.					520	560
Feb....					270	117					390	120
Mar....					240	54.9					475	170
April...					66	115.					410	310
May....					101	43.3					660	585
June...	116.5	1910	1610	31.5	324	98.9	162	1490	1250	850	1600	955
July....	42.6	457	198	134.	333	93.9	190	40,400	7950	5660	2820	2070
Aug....	15.2	1120	168	764.	266	109.	59	2890	3940	2840	9280	3860
Sept....	26.6	452	129	145	387	309	193	2060	5310	3430	13,300	2540
Oct.....	24.7	242	315	201	555	—	165	11,000	4260	800	1970	—
Nov....					75.2	64.9					1440	1190
Dec....					81.1	275.					540	730
1938												
Jan.....					66.9	111					240	495
Feb....					165.	—					230	—
Mar....					155.	135					570	305
Apr....					50.5	79.4					580	550
May....					117	79.1					4170	1980
June...	117.	202	58.7	125	178	74.1	2790	15,200	12,100	3860	35,200	8810

The data in table 3 are arithmetical averages of the base data on the samples collected at each series. They are not weighted averages and therefore do not show the complete or true picture. However, there are a number of observations to be made from this table, including the following:

1. The bacterial content of the river is reduced due to cold weather from November to May. The temperature range for this period is from 0 to 10°C. (Summer range is 10° to 25°C.)

2. During the dry year of 1936, the bacterial concentrations were generally higher than in 1937 and 1938.

3. The apparent decrease in bacterial content from Series C to Series EE is fictitious since a larger quantity of water is polluted at Series EE (i.e., the bacteria are dispersed in a greater volume of water).

4. The bacterial pollution is still in evidence 17 miles below Buffalo. These samples include sewage from three small municipalities which may affect the data. On the other hand, samples collected at this point (Series H) represent an input of relatively weak sewage from Buffalo at approximately 2 to 4 A.M. the same morning. (Hourly studies at Niagara Falls indicate higher bacterial contents at night in this location corresponding to strong daytime sewage from Buffalo.) The effect of other sources of pollution cannot be entirely overlooked, however.

5. The general effect of the Buffalo River on the samples at Series BB, above the Swan Trunk sewer, is shown. Great variations in the bacterial content of the river at this point have been noticeable when, due to a combination of wind, lake level and flow conditions, the Buffalo River spews its septic waters rapidly and farther into the Lake and Niagara River. To this action of the Buffalo River has been traced the fish killing episodes in 1937 which have been reported elsewhere (1).

In order to show the monthly comparisons more easily, the cross-section averages of coliform per ml. are shown for Series EE and H in table 4. These are the only series which include the entire twelve months of the year. Though they apparently indicate a decrease in coliform content as the river moves from one station to the other, this is not strictly true for two reasons. First, a greater volume of water is polluted at the lower station and, secondly, the samples at H represent a weaker sewage input at Buffalo than those at EE. These data do show that even in the cold months, high coliform

contents are possible. When one considers that these average figures represent 50,000 or more cubic feet per second flow, it is easy to realize that the total bacterial population is tremendous.

The truer picture of the bacterial content of the Niagara River is shown by calculating the total quantity units of bacteria. Since flow distribution is known only at Series E and EE, quantitative evaluation of the pollution is possible only at those points. Data at Series E are available only for the summer months. Table 5 lists the total Quantity Units of coliform at these two sampling locations for the months of June through November, with averages.

TABLE 4

Average Coliform Content per ml. at Series EE and H 1936–38

	SERIES EE		SERIES H	
	1936–37	1937–38	1936–37	1937–38
June	230	324	40	99
July	295	333	45	94
Aug	470	266	42	109
Sept	890	387	71	309
Oct	1680	555	127	—*
Nov	180	75	165	65
Dec	120	81	97	275
Jan	180	67	222	111
Feb	270	165	117	—†
Mar	240	155	55	135
Apr	66	51	115	79
May	101	51	43	79

* High winds prevented sampling from boat.

† Ice jams prevented sampling from bridge.

The most striking observation from these data is the actual increase of bacteria in the river though no additional sewage is introduced. Comparisons of the total quantity units of coliform at Series EE with the sewage input (estimated from studies of the sewers, harbor and Buffalo River) indicated an increase in total coliform of five fold. Laboratory studies indicated similar trends. These are discussed below.

Table 6 is presented to show the year round condition as reflected by the weighted data representing the total quantity units at that point. When these data are compared to those in table 4, it appears that the average analysis does not always show the exact condition.

The five months of warm water are obvious by comparison to the seven cold water months, although even in the winter high coliform content is possible.

TABLE 5

Comparison of Quantity Units of Coliform at Series E and EE

MONTH	1936		1937		AVERAGE	
	Series E	Series EE	Series E	Series EE	Series E	Series EE
June	7,829	10,863	2,610	10,000	5,220	10,431
July	26,480	11,524	11,700	15,100	19,090	13,312
Aug	8,736	13,329	7,060	9,360	7,898	11,345
Sept	11,347	50,187	11,300	18,700	11,325	34,443
Oct	49,262	62,503	17,400	20,900	33,331	41,701
Nov	1,622	9,317	—	2,320	1,622	5,818
Average	17,456	26,287	10,014	12,730	13,081	18,508

Note: Distance between E and EE is 2.7 miles.

TABLE 6

Total Quantity Units of Coliform at Series EE 1936–38

MONTH	1936-37	1937-38	AVERAGE
June	10,863	10,000	10,431
July	11,524	15,100	13,312
Aug	13,329	9,360	11,345
Sept	50,187	18,700	34,443
Oct	62,503	20,900	41,701
Nov	9,317	2,320	5,818
Dec	5,888	3,530	4,709
Jan	3,360	1,184	2,272
Feb	12,900	3,946	8,423
Mar	6,730	7,020	6,875
Apr	4,550	2,548	3,548
May	4,370	4,934	4,652
Average			12,294

On the basis of these data, and estimating an average flow in the river of 185,000 c.f.s. of which 30 per cent is polluted, there may be calculated the total number of coliform that passed by Station EE each second. The minimum would be 33 billion and the maximum would be 1,700 billion, or, it might be said that throughout the year

there was an average of 350 billion coliform passed beneath the Upper Grand Island Bridge every second.

The data collected at Series EE will be used in Part 2 of this report as a basis of comparison of conditions before and after sewage treatment.

The Pollution Zone

The extent of the dispersion of Buffalo sewage across the Niagara River is shown by the data in table 7. These data are warm water

TABLE 7

Relative Distribution of Coliform per ml. from American Shore

(Warm Water Data)

SERIES	STATION				
BB	Sta. 2	Sta. 2a	Sta. 4		
0.6 mi.	350	.80	.9		
C	Sta. 2a	Sta. 2	Sta. 3a	Sta. 3	Sta. 4
1.7 mi.	1040	3200	1000	12.	10
D	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5
3.2 mi.	500	700	390	15	1.0
E	Sta. 1	Sta. 1a	Sta. 1b	Sta. 2	Sta. 3
4.1 mi.	550	550	335	15	4.
EE	Sta. 1	Sta. 2	Sta. 3	Sta. 4	
6.8 mi.	730	870	70	0.25	
F	Sta. 1	Sta. 2	Sta. 3	Sta. 4	
9.7 mi.	540	280	18	4.0	
H	Sta. 1-1a	Sta. 2	Sta. 3	Sta. 4	Sta. 5
16.7 mi.	530	165	135	40.	16

averages and are rounded off to even figures to show the relative distribution of coliform per ml. across the channel. The Series F data represent a two-week study at that location with samples being taken every two hours during the daytime.

By referring to fig. 1, it is easy to observe how these data in table 7 were utilized in locating the extent of the pollution zone.

At Series EE, located at the upper Grand Island Bridge, the calculation of the Quantity Units showed that 99.7 per cent of the total coliform content in the east or American Channel was inside the

pollution line as located. Shifting winds naturally have some effect on the location of the pollution zone and it was usually a north-east wind which carried the pollution out far enough to impose greater burdens on the water filtration plants below Buffalo.

Relatively speaking, the data in table 7 show that the coliform content did not drop greatly below Series EE as the river moved toward the Falls. There was, however, some apparent greater spread of bacteria across the American channel as the river neared the lower Grand Island Bridge, at Niagara Falls.

In addition to the regular monthly surveys of the Niagara River,

TABLE 8

Bacterial Content of Intake Water at Niagara Falls, N. Y.

MONTH	COLIFORM/ML.		TOTAL BACTERIA/ML.	
	1936	1937	1936	1937
Jan	14.8	17.3	310	400
Feb	23.4	9.9	400	350
Mar	15.9	17.6	390	240
Apr	11.6	21.1	370	200
May	10.4	7.8	290	220
June	19.9	35.5	740	420
July	77.9	54.9	860	450
Aug	75.7	57.2	1090	330
Sept	82.5	45.4	940	580
Oct	72.5	29.1	380	400
Nov	21.2	18.0	390	280
Dec	14.1	16.7	180	280
Average	36.7	27.5	530	350

daily data were collected on the bacterial content of the raw water at Niagara Falls. These data were furnished by Mr. B. T. Dignan, chemist of the Filtration Plant at Niagara Falls. Table 8 lists the average daily bacterial content at the intake. It is interesting to note that these data compare to Station H-4, which was just inside the pollution zone. Station H-5, approximately 500 feet farther south of H-4 is relatively free from pollution. From computations of analytical data at Series H and comparison with these data in table 8, it appears that prior to 1938 the water at the Niagara Falls intake had a bacterial content of approximately 6 per cent of the maximum content at any cross-section in that vicinity.

Miscellaneous Studies and Data

In addition to the daily data, hourly studies were made in the Niagara Falls Filtration Plant by the Bird Island Laboratory staff on 4 different days. The coliform results for these studies are shown in table 9.

TABLE 9

Hourly Coliform Content per ml. at Niagara Falls, N. Y.

HOUR	9/25/36	9/14/37	9/15/37	9/16/37
9 A.M.	43	130	79	79
10	93	240	70	49
11	93	79	130	79
12 M	43	130	350	170
1 P.M.	43	240	79	79
2	93	49	110	49
3	43	33	79	49
4	240	13	13	130
5	15	24	33	79
6	9.3	79	24	49
7	43	79	33	70
8	240	130	33	33
9	24	33	70	240
10	43	49	70	49
11	43	240	33	33
12 P.M.	93	33	240	130
1 A.M.	240	79	170	130
2	43	170	240	79
3	43	130	110	240
4	460	130	79	79
5	43	70	79	79
6	150	110	17	33
7	39	79	79	79
8	93	49	110	130
Average	94	100	97	90

Generally speaking, from the data in table 9, it appears that the daily sample taken at 9:00 A.M. is only 60 to 80 per cent of the actual daily average. The daily data given in table 8 are, therefore, probably lower than the average load imposed on the filter plant. These hourly samples indicate cycles in the coliform content and also show the effects of flow time from Buffalo to Niagara Falls. The cause of the cycles is not evident, but it may be the effects of sewage from towns between Buffalo and Niagara Falls.

Certain laboratory studies were carried on in connection with this work in which the effect of dilution on raw and chlorinated sewage was studied. These experiments which were set up to simulate conditions in the Niagara River have been reported in a paper on chlorination studies (2), but it is interesting to review them briefly at this time to show their relation to the River Surveys.

Using different temperatures to represent summer and winter conditions, definite quantities of raw and chlorinated-settled sewage were added to different bottles of lake water so that a dilution of 1 to 320 was created. These were stirred at a rate equivalent to the average velocity of the river and kept at constant temperature. Coliform and total bacteria were determined on the original sewage and lake water and every two hours thereafter. In the case where raw sewage is added to a large volume of diluting lake water, the total count tends to decrease at cold temperatures and shows a similar decrease in the first few hours after dilution at warm temperatures, followed by increases up to its original numbers and above some 16 hours after dilution. Coliform at cold temperatures rise and fall in numbers during 24 hours after dilution, sometimes surpassing their original numbers, but never decreasing by more than 50 per cent. At warm temperatures, the coliform increase in the first two hours by 50 per cent then rise and fall between 75 and 25 per cent of the original numbers during 24 hours.

When chlorinated sewage was diluted with lake water at both cold and warm temperatures, there was little tendency for the coliform to grow or increase above the number left in the chlorinated sewage although there was ample food present.

Preliminary data in river studies since July, 1938, indicate a similar occurrence.

Summary

From twenty-five monthly studies of the Niagara River between June, 1936, and June, 1938, inclusive, prior to sewage treatment at Buffalo, the following pertinent facts were observed.

1. The bacterial pollution of the Niagara River, due to sewage from Buffalo, remained within a definite zone, the boundary line of which varied only with strong winds.

2. The polluted zone was no more than 30 per cent of the total flow in the river.

3. The coliform content of the river increased below Buffalo for a number of miles and was still in evidence at Niagara Falls, New York.

4. There were apparently some growth cycles of coliform between Buffalo and Niagara Falls.

5. The total coliform content of the Niagara River below Buffalo in the warm weather was upwards of 15,000 Quantity Units, which in 30 per cent of a flow of 185,000 cubic feet per second was approximately 400 billion coliform per second passing by a point 7 miles below Buffalo.

6. Winter conditions showed the same general trends, but bacterial concentrations were only about $\frac{1}{3}$ of those existing in the summer.

7. The study of Niagara River Pollution by regular monthly surveys has been continued since sewage treatment at Buffalo started and these surveys are planned for several years. After the first year's operation is completed and sufficient data are available to show definite year-round trends, the results will be reported. Indications thus far are that the bacterial content of the Niagara River is greatly reduced.

The Bird Island Laboratory is indebted to the State Department of Health, both for their original reports and their cooperation; to the Conservation Department for furnishing the boat for the surveys; to Mr. Bert Dignan, Chief Chemist of the Niagara Falls Filtration Plant, for the daily data and cooperation in the 24-hour studies; and to Greeley & Hansen, Engineers for the Buffalo Sewer Authority, for hydraulic data and assistance they furnished.

The writers are particularly grateful to Mr. Blake Fraser, Engineer of the Conservation Department boat for skillful piloting during the surveys; to Mr. L. G. Williams and M. LeBosquet, Jr., of Greeley & Hansen, Engineers, for assistance in inaugurating the surveys and in spotting the sampling stations, and to the other members of the Laboratory staff for their assistance in collection and analysis of the various samples.

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(1) Symons, G. E., and Simpson, R. W. Fish Poisoning in the Niagara River in 1937, Transactions of the American Fisheries Society, in press.

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Threshold Treatment of Municipal Water Supplies

Use of Sodium Hexametaphosphate

By Owen Rice and G. B. Hatch

IF SOMEONE had risen in the meeting of the American Water Works Association ten years ago and said, "Here is an inorganic chemical which has been known for a century; one pound of this added to a million pounds of water will prevent deposition of calcium carbonate in your filters, distribution systems, and in the hot water heaters of your customers, and at the same time will have a distinct effect in minimizing corrosion," he might well have been led politely away for a mental examination. If anyone had been inclined to humor him by asking the name of this marvelous substance and he had replied "sodium hexametaphosphate," the sad state of his mind would have been confirmed, for who had ever heard of such a substance in 1929? To be sure, a person blessed with unusual curiosity, on searching the chemical literature, would have found this substance mentioned as more or less of a curiosity, played with by chemists at intervals ever since it was first described by Thomas Graham in 1833. Anyone so foolish as to try to test the statement concerning its unbelievable properties would, however, in 1929, have been reduced finally to making it himself by fusing monosodium orthophosphate and quenching the melt, for it is doubtful whether there was a pound available for purchase in the United States at that time.

Since 1929, when the use of sodium hexametaphosphate in the conditioning of boiler water was first visualized (1), its applications in water treatment have multiplied. It is not the purpose of this paper, however, to review the softening of water by sodium hexametaphosphate as a result of its property of forming a soluble complex with the calcium ion, (2) (3), although this has led to widespread utilization in textile processing, commercial and domestic laundering,

A paper presented on June 15, 1939, at the Atlantic City Convention, by Owen Rice, Research Engineer, and G. B. Hatch, Research Chemist, Hall Laboratories, Inc., Pittsburgh.

the mechanical washing of dishes, bottles, and cans, and to its potential use wherever soap is employed in water containing the calcium ion. The following discussion will be directed instead to the even more startling effect of a few parts per million of sodium hexametaphosphate in preventing scale deposition and minimizing corrosion.

Meaning of Threshold Treatment

Threshold treatment with sodium hexametaphosphate is based upon the discovery of Rosenstein (4) that a concentration of a molecularly dehydrated phosphate of the order of 1 p.p.m. would effectively inhibit the formation of calcium carbonate scale when ammonia was added to irrigation waters. The descriptive name "threshold treatment" has been chosen to cover the general process of preventing deposition of calcium carbonate by this means because apparently the molecularly dehydrated phosphate acts to remove crystal nuclei from contact with the solution on the threshold of the crystallization process, that is, even before the nuclei reach dimensions great enough to exhibit the properties of the colloid state. The name is equally appropriate with respect to the inhibition of corrosion. While at first some confusion may arise in the minds of those accustomed to thinking of taste or odor when the word "threshold" is mentioned in connection with water supplies, there should be little real difficulty in keeping the respective ideas separate.

Among the molecularly dehydrated phosphates are the various forms of sodium metaphosphate, sodium pyrophosphate, and also the so-called polyphosphates. Of this group, sodium hexametaphosphate is the most generally effective and the most convenient to use.

In the following sections an attempt will be made to describe what can be accomplished by threshold treatment of municipal water supplies; to explain how an almost vanishingly small concentration of sodium hexametaphosphate can produce the phenomenal results observed both in the laboratory and in the field; to suggest how the effect may be tested in the laboratory; and to give pertinent information concerning the properties of sodium hexametaphosphate.

Applying Threshold Treatment to Various Water Problems

The operator of a water supply system who is free from worry about scale deposition on one hand or corrosion on the other is a fortunate person and, the writers believe, a rare one. If he has to

deal with a water containing high temporary hardness, loss of carbon dioxide to the atmosphere during aeration or during storage in open reservoirs may cause calcium carbonate to deposit in his distribution system. In any case, he must listen patiently to the repeated complaints of the householders whose heater coils plug up and burn out at unpleasantly brief intervals. If he operates a lime or lime-soda softening plant, he is always burdened with the necessity of keeping both his distribution system and his customer's hot-water systems free of scale. When he does this by recarbonating, his problem of balancing is no less difficult than that of an acrobat riding the high wire on a bicycle. If he turns to zeolite softening or if he has the somewhat dubious blessing of a naturally soft supply, his thoughts are usually on red water or tuberculation. Threshold treatment has something to offer in each of these cases. It has also revived interest in the lime-zeolite system of softening, which hitherto had encountered corrosion difficulties when recarbonation was employed to prevent deposition in the zeolite bed.

Stabilizing Water Against Deposition of Calcium Carbonate

Data previously presented (5) have been recast in fig. 1 to show how much calcium carbonate can be held in solution by threshold treatment with 2 p.p.m. of sodium hexametaphosphate when waters of differing degrees of hardness are heated for one hour at various temperatures. How much more calcium carbonate is held in solution under these conditions than when the untreated water is heated in the same manner is shown in fig. 2. For example, when a synthetic water containing temporary hardness equivalent to 400 p.p.m. $CaCO_3$ was heated for 1 hour at 60° C., the presence of 2 p.p.m. of sodium hexametaphosphate held all of this in solution, as shown in fig. 1, while in the absence of threshold treatment 90 p.p.m. of calcium carbonate would have precipitated, as shown in fig. 2.

The indications from these laboratory experiments have been fully substantiated in practice, where threshold treatment has prevented the deposition of scale on heating waters of such varying compositions as those shown in table 1.

When used in connection with lime or lime-soda softening, threshold treatment may be applied to the filtered water to prevent after-precipitation in the distribution system while gaining the softening effect of precipitation on the filter sand, or it may be applied to the settled water to prevent this incrustation of the filter. Anyone

applying it inadvertently ahead of the softener is likely to be somewhat perplexed by the results.

While a threshold amount of sodium hexametaphosphate will interfere with the satisfactory operation of a softener at ordinary temperatures, the effect on a hot-process softener is less marked. If

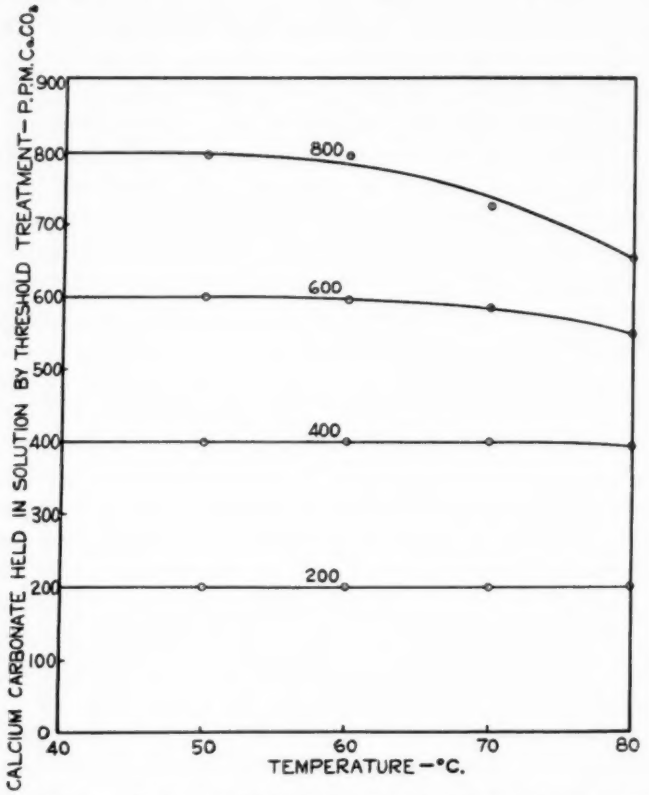

FIG. 1. Calcium Carbonate Held in Solution by Threshold Treatment on Heating Water of Varying Degrees of Temporary Hardness for 1 Hour at Various Temperatures.

the retention time is long, or the excess of lime is considerable, or the temperature is kept near the atmospheric boiling point, little or no effect will be detected, due to reversion of the metaphosphate or its adsorption on the sludge.

In preventing after-precipitation from lime-softened waters, threshold treatment is effective even in the presence of excess caustic

alkalinity. Typical average analyses are shown in table 2 for waters which prior to threshold treatment consistently deposited calcium carbonate following the softener, but from which further deposition,

TABLE 1

Typical Waters from Which Deposition of Calcium Carbonate on Heating Has Been Prevented by Threshold Treatment

ION	CONCENTRATION P.P.M.			
Bicarbonate (HCO_3)	282	323	475	209
Chloride (Cl)	33	95	36	28,500
Sulfate (SO_4)	—	—	173	62
Silica (Sio_2)	—	—	15	128
Calcium (Ca)	82	174	135	1,670
Magnesium (Mg)	21	49	40–50*	493

* Estimated.

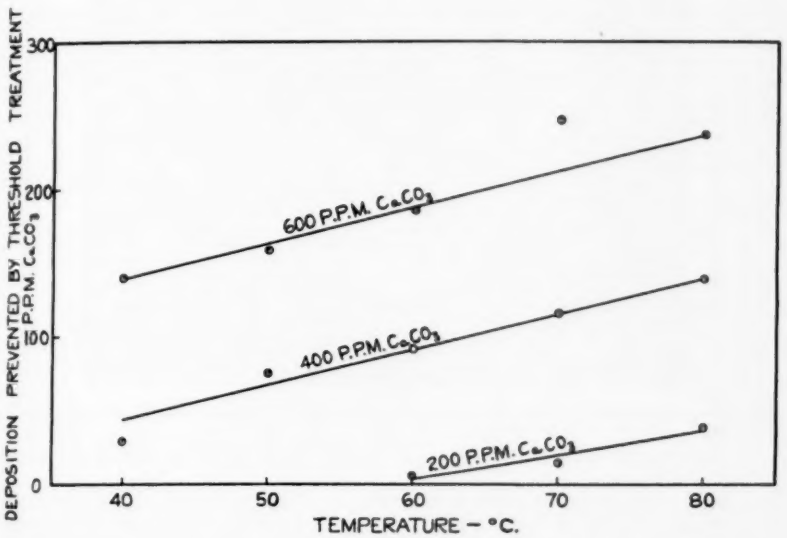

FIG. 2. Amount of Deposition Prevented by Threshold Treatment on Heating for 1 Hour at Various Temperatures.

both in the cold and on heating, has been prevented by the use of 1 or 2 p.p.m. of sodium hexametaphosphate.

The prevention of the precipitation of calcium carbonate in a system already containing a deposit of this substance by threshold

treatment is shown graphically in fig. 3. Synthetic waters prepared so that they would be supersaturated with respect to calcium carbonate were passed through a bed of incrusted filter sand comprising particles similar to the one shown in cross-section in fig. 4. The drop in total alkalinity of the effluent was used as a measure of the amount

TABLE 2

Typical Lime-Softened Waters, Containing Excess Caustic Alkalinity, from Which Deposition of Calcium Carbonate Has Been Prevented by Threshold Treatment

CHARACTERISTICS, AS $CaCO_3$	P.P.M.		
Hardness	13	20	117
Alkalinity to: phenolphthalein	60	86	69
methyl orange	75	104	95

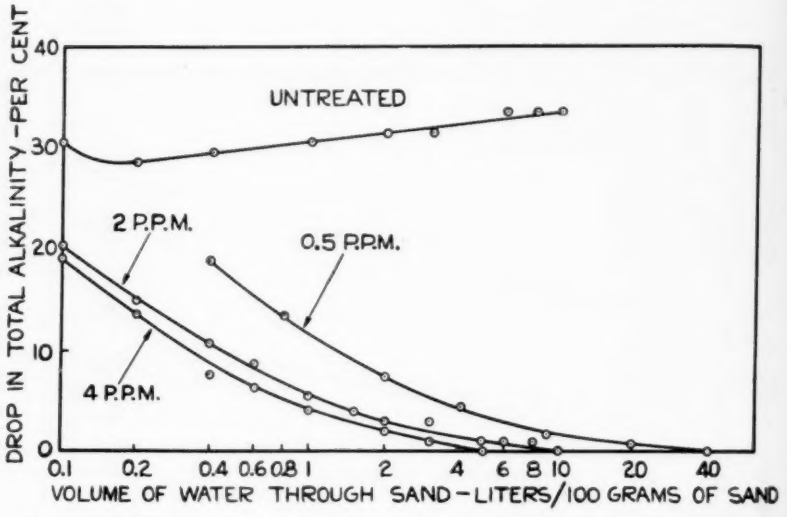

FIG. 3. Inhibition of After-Precipitation on Incrusted Filter Sand by Threshold Treatment with Various Concentrations of Sodium Hexametaphosphate.

of precipitation taking place on the sand. While the untreated water continued to show a drop in alkalinity of about 30 per cent throughout the test, in the case of each of the threshold-treated waters, the precipitation decreased steadily until it ceased entirely.

It is evident from fig. 3 that, while precipitation of calcium carbonate was ultimately prevented in each case where the water contained

sodium hexametaphosphate, when the concentration was only 0.5 p.p.m., four times as much water was required to stop precipitation as when the concentration was 2 p.p.m., and eight times as much as when the concentration was 4 p.p.m. While it will be noted that these results indicate the amount of sodium hexametaphosphate required to saturate the encrusted sand to be independent of the concentration, too great stress should not be placed upon this observation in view of the difficulty of precisely determining the exact

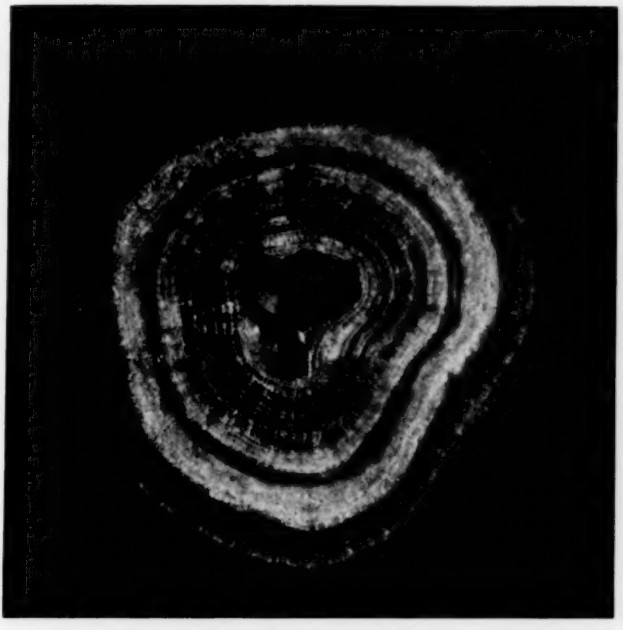

FIG. 4. Cross-Section of Grain of Incrusted Filter Sand. 25×. Note Cementation of Two Original Sand Grains.

point at which the alkalinity drop becomes zero, the experimental method not allowing accurate determination of alkalinity differences below 1 p.p.m. Obviously, however, when threshold treatment is applied to a distribution system rather completely lined with calcium carbonate, the time required to block off the precipitation process will depend on the concentration employed. In one test application previously reported, (6), after-precipitation had ceased at a point three miles from the plant within four days after introduction of sodium hexametaphosphate at the rate of 2 p.p.m. was begun.

Threshold treatment slowly removes old scale as well as preventing deposition of new material. Occasionally, operators have regarded this as a source of worry, fearing that the rate of removal would be rapid enough to produce a turbid water. These fears have proved unfounded since no noticeable increase in turbidity has occurred in plants where threshold treatment has been adopted. Two factors appear to exert considerable effect upon this rate of removal: the temperature and the water velocity. The function of the hexametaphosphate appears to be to loosen the bonds between the individual crystals making up the scale, converting it to a sludge, this action being considerably accelerated at the higher temperatures. Whether or not this sludge will be rapidly removed depends upon the water velocity. At the normal temperature of a distribution system the rate of removal of old scale will be quite slow. The effect of water velocity is in a desirable direction, since the greater the demand upon an incrusted line the more rapid the removal of the scale will be.

Use on Naturally Soft or Zeolite-Softened Water

When iron is corroded by water, the ultimate product of hydrated iron oxide may either be carried along to appear as "red water" from the customer's tap, or it may be precipitated over the regions of corrosion. Red water is commonly associated with relatively low pH and may be cured in many cases by the addition of lime, caustic soda, or soda ash. Frequently, however, this type of treatment fails to stop the corrosion process and instead simply prevents red water by precipitating the iron oxide, thus increasing tuberculation. It is true that at a sufficiently high pH, above the level usually preferred in water for human consumption, corrosion may almost completely disappear as the result of the formation of a relatively continuous and compact coating of iron oxide.

The use of a thin layer of calcium carbonate scale for corrosion control appears attractive to many. Unfortunately, its practical attainment has proven difficult due to the tendency for heavy precipitation near the plant, leaving the outlying sections of the distribution system unprotected. This difficulty may be overcome by using amounts of sodium hexametaphosphate insufficient to completely prevent precipitation. "Sub-threshold" treatment in this manner is already being successfully used in several municipal water plants to spread the calcium carbonate deposition throughout the system.

When threshold treatment is used for the complete elimination of scale deposition one might expect an increase in corrosion, but actually such is not the case. Threshold treatment with a sufficient concentration of sodium hexametaphosphate definitely inhibits corrosion, at the same time keeping the metal surface free of scale.

Laboratory corrosion tests on black iron pipe have indicated that threshold amounts of hexametaphosphate exert a very pronounced inhibitory action upon the corrosion not only at high, but also at low pH values, for example pH = 6. In fact, the inhibitory action appears even more pronounced at the lower pH values. The small amount of corrosion which occurs in the presence of threshold quantities of hexametaphosphate forms rust which is darker in color, appears much more dense, and is more tightly adherent.

To those who give greater weight to field experience than to laboratory experiment, it should prove significant that, with threshold treatment in use in hundreds of plants to obviate calcium carbonate scale in condensers and heat exchangers of all types, not one case of corrosion of the metal surfaces laid bare and kept bare by the treatment has been reported, although specific information has been requested on this point from many plants where trouble might be anticipated.

What Makes Threshold Treatment Work?

The usual first reaction to any statement of what threshold treatment does is justifiable skepticism, more or less polite. After the initial statement of, "It can't work," has been refuted by argument or by test, almost inevitably comes the question, "How does it do it?" To this question it is possible to give only a provisional answer at the present time.

In brief, it is believed that the precipitation of calcium carbonate is prevented by threshold treatment because the sodium hexametaphosphate has the ability to segregate nuclei of calcium carbonate as rapidly as they develop in the water, so that in effect it is possible to stabilize a condition of even rather extreme supersaturation with respect to this substance. It has been found that sodium hexametaphosphate is very strongly adsorbed on the surface of many metals, metal oxides and salts. No undue exercise of the imagination is required, therefore, to picture the adsorption of metaphosphate whenever calcium and carbonate ions begin to build from solution

the lattice of what is referred to as a crystal nucleus. By isolating each nucleus, as it is formed, from further contact with the water its growth into a microscopically observable crystal is prevented.

Where calcium carbonate has already been deposited from a water as in the experiment with incrusted filter sand shown in fig. 3, enough sodium hexametaphosphate must be supplied to cover this surface in order completely to inhibit further crystallization from solution.

An adsorbed film which can, in effect, shut off calcium carbonate from contact with solution so completely that no further crystal growth occurs might well account for the observed effect of sodium hexametaphosphate upon the rate of corrosion of an iron surface. Indeed, it has been noted in experiments with iron pipe in the laboratory that a metal surface over which threshold-treated water is passed for a long period of time frequently develops characteristic interference colors, although no phosphate deposit can be observed. While continued investigation may reveal more clearly the fundamental mechanism by which sodium hexametaphosphate produces its remarkable effect in threshold treatment, it seems evident that formation of a film, perhaps only of molecular dimensions, is involved.

Experimental Testing for Scale Prevention

It is frequently the case that numerous difficulties are encountered in adapting to practice a process developed in the laboratory. In the case of threshold treatment the converse appears to hold, for in general more trouble has been encountered in laboratory tests than in actual applications. Failure to recognize the strong adsorption of hexametaphosphate upon many solid surfaces, and the consequences thereof, accounts for most of the trouble. Some discussion of how the individual operator may best investigate threshold treatment seems in order.

Surfaces having a high affinity for hexametaphosphate must be exposed to sufficient threshold-treated water to effectively saturate them with respect to hexametaphosphate before complete prevention of calcium carbonate deposition can be attained (see fig. 3). A further consequence of this adsorption is that surfaces once saturated with hexametaphosphate, when subsequently exposed to untreated water, exhibit a definite lag, or hysteresis, before attaining their original power of relieving supersaturation with respect to calcium carbonate.

When the usual stability test, consisting of shaking the water with

powdered calcium carbonate and determining the resulting change in alkalinity, is applied to a water containing 2 p.p.m. of hexametaphosphate a rather low stability is indicated, there being insufficient hexametaphosphate present in the small volume of water tested to saturate the relatively large surface of calcium carbonate. If the test is successively repeated using the same sample of calcium carbonate with successive quantities of threshold-treated water, successively higher stabilities are indicated until the calcium carbonate surface becomes saturated with respect to hexametaphosphate (7).

Modification of Stability Test

A modification of the stability test more suitable for testing threshold-treated waters consists of passing the water at a constant rate through a column packed with calcium carbonate, as described by Enslow (8) and illustrated in fig. 5, and measuring the drop in alkalinity of the effluent as a function of the volume of water passed through the column. Incrusted filter sand offers a convenient source of calcium carbonate particles for such an experiment since it can be easily sized and its surface area readily calculated. The curves of fig. 3 were obtained by passing through 100 gm. of 12/14-mesh incrusted filter sand a water having a hardness of 50, phenolphthalein alkalinity of 70, and total alkalinity of 102 p.p.m. as calcium carbonate. These curves illustrate the apparent increase in stability of the threshold-treated waters with progressive flow through the sand, in contrast with the behavior of the untreated water which remains at a low stability. If only the drop in alkalinity of the initial portion of water passing through the sand had been taken as a measure of the stability of the water an entirely misleading idea would have been obtained.

In measuring the stability of a water by this continuous-flow procedure it is always advisable, because of the hysteresis effect, to use a fresh portion of incrusted sand in each test. Once the surface of the incrusted sand has been saturated with hexametaphosphate, the passage of an appreciable quantity of untreated water through the sand is required before the normal alkalinity drop, characteristic of the water, is obtained. Just as a certain quantity of threshold-treated water is required to saturate the calcium carbonate surface, a certain quantity of the untreated water is required to "de-saturate" the surface. If the behavior of an untreated water were judged by the alkalinity drop resulting upon the passage of the initial portions

of the water through an incrusted sand which had previously been exposed to threshold-treated water, an erroneously high stability would be indicated.

The hysteresis effect, or carryover of threshold treatment, is not limited to cases involving calcium carbonate surfaces, but exists with

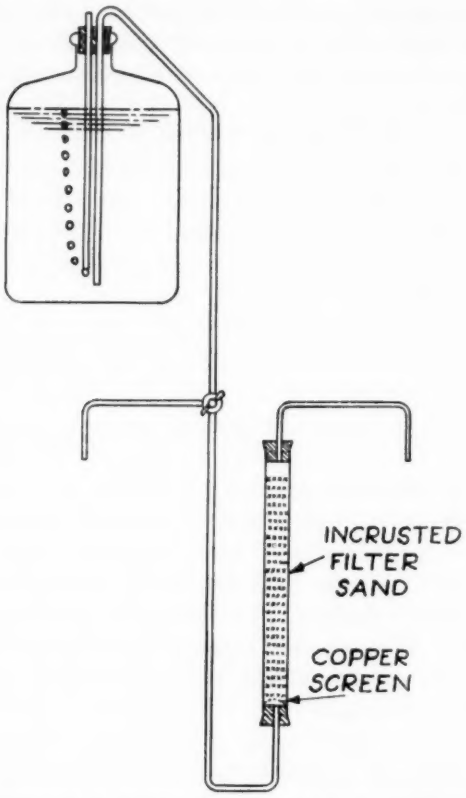

FIG. 5. Arrangement of Enslow's "Stability Indicator" Used to Show the Effect of Threshold Treatment on the Precipitation of Calcium Carbonate.

numerous other surfaces. For example, once a brass or copper heating surface is exposed to threshold-treated water, the calcium carbonate deposition thereon from an untreated water attains its normal value but slowly. No indication of such a carryover effect has been observed upon glass surfaces.

Experiments on Corrosion Prevention

In the laboratory the inhibiting action of a few parts per million of sodium hexametaphosphate on the corrosion process may be demonstrated by passing a continuous stream of water through steel wool contained in a glass tube. Parallel experiments with treated and untreated water will show a difference easily observable in an hour or two. If the flow of water to each tube is maintained at a constant rate, the pressure on the inlet side of the tube carrying untreated water will rise progressively as hydrated iron oxide tends to plug the interstices of the steel wool, while in the experiment with the treated water the pressure will remain substantially constant. Measurement of the oxygen content of the influent and effluent water supports the visual evidence, showing that oxidation of the steel wool in contact with the threshold-treated water occurs at a rate which is only a small fraction of that in the case of the untreated water.

Just as in the case of the prevention of precipitation upon calcium carbonate surfaces, it is necessary to saturate effectively the steel surface with hexametaphosphate before maximum protection against corrosion can be attained. In the laboratory tests it has been observed that most of the corrosion which does occur with the threshold-treated waters takes place at the start of a test.

Properties of Sodium Hexametaphosphate

The person convinced that threshold treatment does work, and content to accept for the time being the tentative explanation of how it works, usually asks next "Is it safe to use sodium hexametaphosphate in water intended for human consumption?" The best answer to this comes from feeding experiments on animals conducted both in this country and in Great Britain. In one set of experiments four groups of rats were supplied for six weeks with drinking water containing respectively 0, 2, 20 and 200 p.p.m. of sodium hexametaphosphate. There was no significant difference between the average increase in weight in the various groups and all remained in a completely healthy condition. The lack of any adverse effect of sodium hexametaphosphate, even when used in concentrations many times greater than those employed in threshold treatment, was confirmed at the end of the six-week test by examination of the bone structure of the rats.

In other experiments with rats, additions of sodium hexametaphosphate to the diet in amounts corresponding to 5 and 10 per cent by weight of their total food intake did not produce any toxic effects (9). These results have led already to the approval of threshold treatment for use in municipal water supplies in fourteen states where permission has been requested.

Sodium hexametaphosphate is a sodium phosphate glass produced by a furnace process from phosphoric acid and soda ash. It is obtainable commercially in a highly purified form prepared from food-grade phosphoric acid. It is readily water-soluble to give solutions of any convenient strength, which may be fed into an open system by simple gravity feeders or by more accurate proportioning pumps such as are now widely used for the feeding of hypochlorite. It does not interfere in any way with the feeding or the function of the other chemicals used in water treatment, with the exception, of course, that it should not be introduced ahead of the coagulation basins, since, due to its strong adsorption, it interferes with floc formation as well as cold-process softening. It does not, however, disperse floc previously formed and so may be added before filtration. The concentrated solutions slowly dissolve most of the ordinary metals but stainless steel is practically unaffected. Solutions of sodium hexametaphosphate of any strength are not only absolutely harmless to the skin but actually exert a beneficial action upon it (10).

Conclusion

Corrosion might be said to date back to the time when our prehistoric forbears first began to use metal. The use of lime for softening water began a century ago, only a few years after sodium hexametaphosphate was first described by Thomas Graham. In retrospect, it seems as if it had taken a long time to rescue sodium hexametaphosphate from limbo and to apply it, in what is now referred to as threshold treatment, for the prevention of calcium carbonate deposits and the control of corrosion. The rapid acceptance of threshold treatment in the three years since Rosenstein's discovery was first made public indicates how much it was needed, but, in fact, the writers believe that the full possibilities are still to be realized and hope to be able to offer additional data in the near future.

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Bacteria, Corrosion and Red Water

By T. E. Larson

MANY investigators have devoted years to the study of corrosion. Numerous phases of this complex problem have been solved or eliminated but many are left unsolved and are complicated by a variety of new as well as old factors—factors found to prevent corrosion in some cases and to increase corrosion in others.

The question is definitely one which involves chemical reactions,—reactions which are known to be possible but vary in rate and which can be stopped or aided by side reactions. "How fast does the reaction take place?" "How long will the reaction continue?" These two questions are answered by the controlling factors. Control the rate, and corrosion may be minimized or stopped.

The present day control consists of using a protective coating composed of a substance unreactive to water and oxygen. Perhaps the most elementary protective coating is a film of hydrogen constituting the overvoltage phenomenon.

It is well known that pipe effectively lined with enamel, cement, asphalt, or coal tar is not subject to metallic corrosion. In every case, with the possible exception of cement, the coating must be firmly adherent and without breaks or pinholes which have been pointed out to be often more harmful than if the pipe were not coated at all. Concentrated attack may take place at these points to pierce through the metal long before general corrosion could weaken the structure.

Softened or naturally soft water properly treated with lime soda, caustic soda, soda ash or sodium silicate has also been found to prevent metallic corrosion when a good adherent, unbroken calcium carbonate or silicate coating has been laid down and maintained. It is essential that this coating be complete and maintained.

A paper presented at the Illinois Section meeting, Urbana, Illinois, April 21, 1939, by Dr. T. E. Larson, Chemist, State Water Survey, Urbana, Illinois.

Oxygen becomes almost a necessary evil when it is essential that aeration be the means of iron and gas removal, or taste and odor control. Corrosion has been shown to take place almost in proportion to the dissolved oxygen content in natural water (1). On the other hand dissolved oxygen can also aid in the inhibition of corrosion (2, 3, 4) by aiding in the deposition of calcium carbonate with ferric hydroxide at the point of corrosion reaction. Here the question is tied up with the velocity of flow and the various concentrations of negative ions.

"Red water," the cause of numerous complaints may be from either of two sources. Iron may be present in the raw water in which case there is no hope of alleviating staining and bacterial growths without removal of the iron by an accepted standardized procedure. The other source is by corrosion of the distribution mains or service lines. It may be well to state the question of the rate of corrosion in another way: "How much time is available for corrosion to take place?" This will be discussed later.

The plague, or should I say one of the plagues, of the water works man's life, consists of placing a clear, colorless, odorless water into the distribution system at the plant and finding consumers complaining of obtaining dirty, red, smelly water from their tap. That's discouraging.

Most Illinois waters are moderately hard or hard and unsoftened. The addition of chlorine or chloramine, frequently accompanied by iron removal is in most cases the only treatment used, if any. This is typically exemplified by the University of Illinois water. Here only two peculiarities may be noted. The alkalinity of 330 p.p.m. is greater than the hardness of 280 p.p.m. and ammonia nitrogen is present in the raw well water to the extent of 1.5 to 2.5 p.p.m. The sodium bicarbonate presence is not considered to be a decisive factor in connection with "red water," but the ammonia content has been found to be a new if not a potent factor.

Treatment at the University plant consists of iron and gas removal by coke tray aeration, sand filtration, and chlorination. As it leaves the plant the water is iron free by test, has a chloramine content of more than 1.0 p.p.m. and has a dissolved oxygen content less than 8 p.p.m.

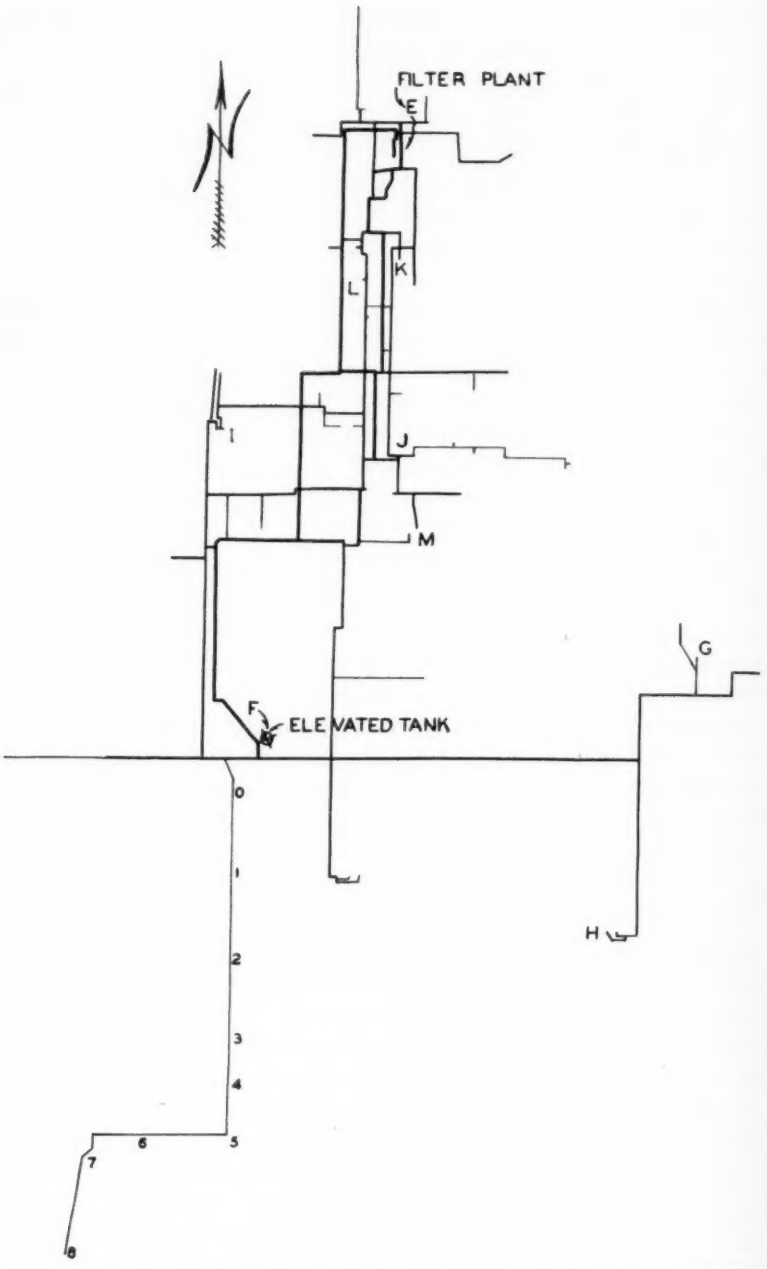

FIG. 1. University of Illinois Distribution System, exclusive of lines smaller than four-inch.

A rough diagram of the distribution system is shown in figure 1. Despite the condition of the water produced at the plant at the north end of the campus, frequent complaints of "red water" are received from various points throughout the system particularly at the south end two miles away. This condition could arise from two sources: first, from old deposits left in the mains before the treatment plant was installed; second, from present corrosive conditions in the mains. A rigorous flushing schedule has alleviated much of the trouble and has reduced complaints considerably, but the dilemma persists and at the far south "dead" end, iron water is had within twenty-four hours after flushing. Old deposits in the mains cannot fully account for occasional soluble ferrous iron content of as much as 8 p.p.m. Corrosion must at least in part be the answer here. Microscopic examination of "red water" sludge from service lines and of deposits in the mains has in no case disclosed the presence of iron bacteria.

In general, complaints increase with increasing distance from the plant. This is in part due to the fact that the velocity of flow decreases with increase in distance from the plant. The iron dissolved or the decrease in dissolved oxygen per unit distance traveled by a unit volume of water near the plant is far less than that at the outer ends of the distribution system. To establish a comparable time-basis, consider the time for one cubic foot of water to pass or come in contact with one square foot of iron surface.

Computation of Contact Time

As water leaves the University plant (1,250,000 gallons per day through a 14-inch main) the average time of contact for one cubic foot of water per square foot of pipe surface is 0.15 seconds. If corrosion does take place, the drop in dissolved oxygen is slight and the increase in iron per unit volume of water is relatively minute. As the water is drawn outward away from the plant it can be seen that the time of contact may approach infinity as the rate of flow approaches that of a "perfect dead-end." Assuming that one-sixth of the water reaches the south campus at the water tower, the time of contact per cubic foot of water (200,000 gallons per day through a 12-inch pipe) per square foot of pipe surface is 0.87 seconds or six times as much as at the plant. Continuing outward to a so-called "dead" end (1000 gallons per day through a 4-inch main) the time of contact is 58 seconds, or 400 times as much time is available for corrosion to take place and iron to be picked up by the water.

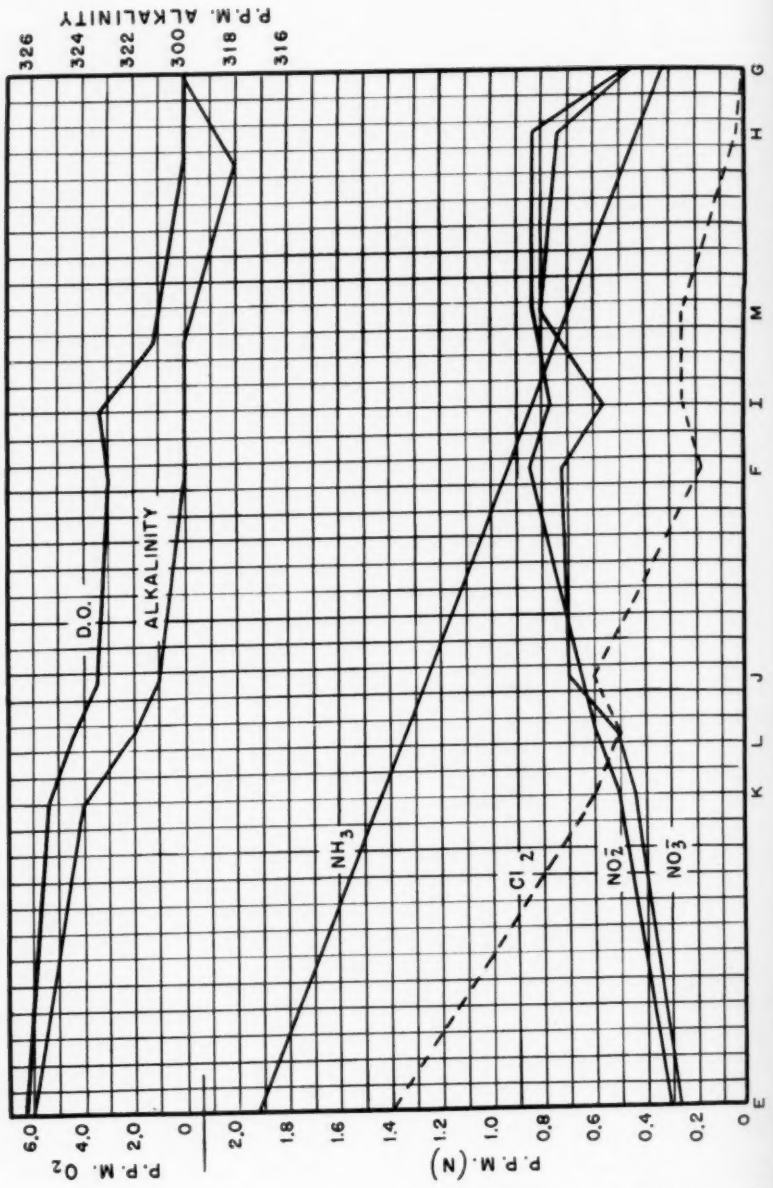

FIG. 2. Typical Variations as water is distributed from north to south ends of campus (left to right).

One other factor has been found to be present to affect the rate of corrosion. It has been noticed that a zeolite filter using the University water reduced the dissolved oxygen to zero. Further tests with a sand filter produced the same effect and it was also found that on passage through the filter that the ammonia content of the water decreased and the nitrite content increased. H. L. White, Sanitary Engineer of the University of Illinois, has noted an increase in the nitrite concentration on passage through the filters at the plant. Nitrite interference has been noticed in tests for chlorine at outer ends of the distribution system.

Accordingly seven series of analyses were made on samples of water collected from various points in the system. The constituents determined included ammonia, nitrites, nitrates, dissolved oxygen, free chlorine, iron, alkalinity, and 37° and 20° incubation bacterial counts. A typical series is indicated in table 1 and fig. 2.

TABLE 1

Typical Trend of Data Throughout Distribution System

(Results in parts per million)

	D FILTER EFFLUENT	E FILTER PLANT SERVICE	K CHEMISTRY BLDG.	J NEW AGRI. BLDG.	L WOMEN'S BLDG.	F ELEVATED TANK	I HUFF GYM	M DAIRY MFG.	H ROUND BARNS	G PREXY HOME
Ammonia – N	1.92	1.92	1.44	1.26	1.34	.94	.84	.70	.42	.34
Nitrite – N	.23	.32	.50	.65	.60	.85	.77	.85	.84	.46
Nitrate – N	.26	.28	.44	.70	.52	.72	.56	.80	.74	.45
D.O.	6.3	6.2	5.4	3.4	4.4	3.0	3.4	1.2	0.0	0.0
Cl_2	1.8	1.4	.6	.6	.5	.18	.25	.25	.03	0.0
Fe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.62	.08
Alk.	326.	326.	324.	322.	321.	320.	320.	320.	318.	320.
6 da. 20°C. bact. count	0	0	0	0	26	600	5000	2000	1600	1500

In general the data indicate that with increasing distance from the plant, the dissolved oxygen, the ammonia, and free chlorine decrease while the nitrites, nitrates and six-day, 20° bacterial count increase. Figure 2 indicates the trend in values with reference to the ammonia content.

In order that ammonia be oxidized to nitrites or nitrates the ratio of the loss in dissolved oxygen to the loss in ammonia-nitrogen must

be 4.0 or 5.15 respectively. In no case was this ratio less than 4.0. The average ratio was 6.0. Thus it may be deduced that no more than one-third and possibly not less than one-sixth of the oxygen is lost to corrosion. For the greater part it is used in converting ammonia to nitrites and nitrates.

Ammonia oxidation to nitrites has been reported (5, 6, 7) previously to take place in filter beds when ammonia was used in conjunction with chloramine. With ideal conditions for bacterial growth it has been attributed and later shown by Feben (8) to be due to bacterial action. Cultures of these bacteria, specific in their ability to convert ammonia to nitrites, have been isolated from the filter beds by Feben. These bacteria were found to be resistant to 2.0 p.p.m. chlorine. No concentrated effort has been made in this study as yet to isolate these bacteria since they will not grow on ordinary media and are difficult to isolate. Despite the ordinary Standard Methods 37° counts and coliform test results of zero, the 20° counts can be consistently shown to be over 1000 bacteria per c.c. at certain localities in the system. At least some twenty different types of bacteria other than these are known to be present in the system. Also, many years of previous study by the State Water Survey on the action of nitrifying bacteria have shown the action indicated in this study to be undoubtedly bacterial.

A slight but definite general decrease in alkalinity is noted. Were it not for the consistency of this trend, it would be attributed to inconsistency in the raw water alkalinity. However, in no one series of the tests made was the alkalinity in the system greater than or equal to that of the filter effluent. This would indicate a slight deposition of calcium carbonate in conjunction with corrosion by

$$Fe(OH)_2 + Ca(HCO_3)_2 \rightarrow CaCO_3 + FeCO_3 + 2H_2O$$

to give calcium carbonate in conjunction with ferrous and ferric oxide. Then too, any bacterial growth requires a source of carbon such as carbon dioxide. Calcium carbonate deposition is further confirmed by analysis of deposits collected from a north campus main in September, 1938. The analyses indicated that only one of every seventeen ferrous iron equivalents is replaced by calcium carbonate. Due to the high rate of flow at this point, the iron that goes into solution per volume of water is very slight and undetectable by analysis.

Corrosion at this main was not noted to be particularly severe but it was definite and of two forms. Small, single and collective tubercles were noted having their origin at pinholes in the bituminous lining. These were hard, compact and often grown together, and were easily picked off with a penknife. Loose, slimy, black mud appeared at pipe joints and extended to either or both sides of the joint for various distances. Its source is quite possibly due to deposits laid down before the treatment plant was installed to remove iron and traces of hydrogen sulfide. Galvanic action may enhance corrosion here, but the fact that a strong hydrogen sulfide odor was given off from acidified samples of this mud indicates some old deposition. This mud as well as the tubercles was coated on the water side by a hard, yellow-brown crust. The velocity of flow here was quite high and after aeration was installed, the dissolved oxygen was rapidly fed to the ferrous oxide on the pipe walls to produce the ferric oxide-calcium carbonate crust. This outer coating does not appear to be sufficiently impermeable to prevent corrosion but appreciable inhibition is afforded.

In connection with bacterial action it is interesting to note that although the dissolved oxygen is partially used up in oxidation of ammonia instead of corroding the iron, this oxidation converts a basic ion into an acidic ion thereby producing two equivalents of acid from one equivalent of a neutral salt. In other words, the loss of one ammonia equivalent produces two free acid equivalents.

$$NH_4HCO_3 + 3O \rightarrow HNO_2 + H_2CO_3 + H_2O$$

Although bacterial protoplasm contains some three and one-half times as much carbon as nitrogen and some of the free carbon dioxide is used up here, only a very small percentage of the ammonia loss is converted to protoplasm. Consequently little of the carbonic acid produced is used up in this manner.

Although the ammonia lost per volume of water is slight, the acidic condition can be expected to be greater at the pipe walls where the bacteria are to be found. This permits two corrosion enhancing conditions. First, a decrease in the protective action of calcium carbonate and ferric oxide is to be expected. Second, oxidizing agents are available to continue corrosion in lines where the dissolved oxygen is depleted. The latter effect is exemplified by the conditions in the far south "dead" end of one mile length. The dissolved oxygen

entering this main is less than 1 p.p.m. and is rapidly depleted. Nevertheless the iron at the exit has been found to be as high as 8.0 p.p.m. In the meantime nitrites and nitrates are reduced from 1.0 to 0.1 and from 0.7 to 0.2 p.p.m. respectively (table 2 and fig. 3). The data in this figure are plotted according to distances in feet as

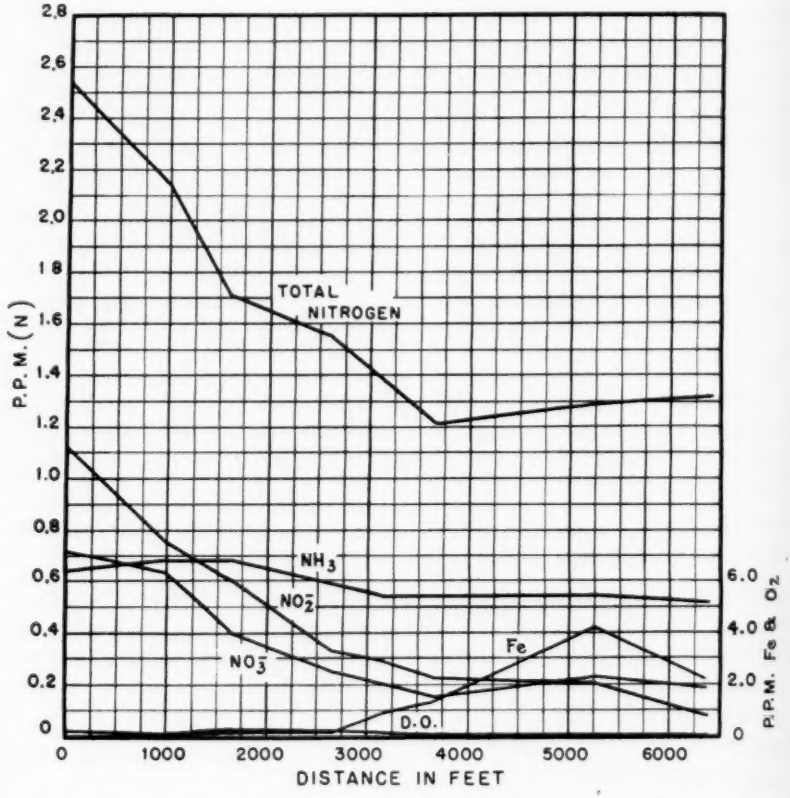

FIG. 3. Typical Variations in "dead" end (four-inch) after oxygen is depleted. (73 sec. per cu.ft. water per sq.ft. pipe surface).

measured between sampling points. Here anaerobic bacterial action is strongly suggested.

Perhaps it should be mentioned that analyses for such low concentrations of ingredients showing such low differences in magnitude are sometimes questionable but the consistency and direction of change in these constituents nullifies any doubt of their validity.

Summary

A certain water may be only slightly corrosive in one part of a system and strongly corrosive in another due to the difference in time of contact for corrosion to take place per unit volume of water. The concentrations of chemical constituents affecting the rate of corrosion can change during passage through the system to alter the rate which controls corrosion. A classification of waters as corrosive and not corrosive cannot be made without placing restrictions on all factors affecting the rate.

Dissolved oxygen in this water system gives rise to conditions which may inhibit or enhance "red water." Inhibition is experienced by the formation of a more or less protective ferric oxide-calcium carbonate coating in the mains which can hinder penetration of dissolved oxygen to the metal itself as well as prevent corrosion products from sloughing off. The presence of ammonia and oxygen as a source of energy for bacteria gives rise to bacterial growths in the mains. Corrosion is enhanced by the bacterial transformation of basic ammonia and oxygen to acidic and oxidizing nitrites and nitrates.

The determination of the depletion of dissolved oxygen throughout this system is not a true measurement of the degree of corrosion. Depletion of dissolved oxygen at the "dead" ends and service lines of the system gives rise to a condition where ferrous iron is not

TABLE 2

Typical Low Flow Data

(Results in parts per million)

	SAMPLING POINT							
	0	1	2	3	4	5	7	8
Ammonia – N	0.64	0.68	0.68		0.54	0.54	0.54	0.52
Nitrite – N	1.12	0.75	0.60	0.33	0.29	0.22	0.21	0.08
Nitrate – N	0.72	0.63	0.39	0.25	0.2	0.15	0.23	0.19
Kjeldahl – N	0.70	0.76	0.72	0.98	0.88	0.84	0.84	1.04
(Kjeldahl + nitrite + nitrate) – N	2.54	2.14	1.71	1.56	1.37	1.21	1.28	1.31
D.O.	0.2	0.1	0.2	0.2		0.0	0.0	
Alk.	318.	318.	320.	314.	316.	316.	314.	314.
Fe	0.	0.	.08	.08	.88	1.32	4.16	2.16

oxidized to insoluble ferric oxide and solution of iron to the ferrous state takes place at the expense of the nitrite and nitrate previously formed—quite possibly by bacterial action.

What corrosion that does take place in the system as a whole is magnified by the accumulation of traces of the iron in the gelatinous masses of bacterial growths clinging to the pipe in localities where the velocity of flow is low and sloughing off occasionally.

We are deeply indebted to Mr. White and his staff at the water plant without whose splendid cooperation a study in this manner could not have been accomplished.

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Determining Residual Ammonia in the Presence of Chloramine

By P. W. Frisk and A. J. Conrad

IT SEEMS to be the opinion of some investigators and workers dealing with the subject of chloramines that Nessler reaction would give a quantitative test in the presence of uncombined ammonia in chloramine solution. This was somewhat doubted by the authors, due to the fact that in actual practice there was found the same amount of ammonia as was added in a process water. From previous experience, we were certain that chloramine had been formed, due to the maintained residual when using chlorine and ammonia, against when using only chlorine. The chlorine dissipation, when exposed to direct sunlight in the settling basin, was very rapid in comparison with using ammonia with chlorine. We also had observed some slime growth in places where the water was heated to from 45° to 50°C. and allowed to be exposed over large aeration surfaces.

This indicated that possibly we were adding too large an amount of ammonia, which, if not combined, would merely be a good nutrient. We then investigated the possibility of determining this ammonia.

On a practical basis, we reduced the ammonia until we observed a loss of chlorine through the settling basins. This observation was made during the day and night and it was quite obvious that the sunlight had a very marked effect on the chlorine residual. This confirms many other investigators' observations.

Our chlorine-ammonia ratio was finally brought down from 1:4 to 1:6 before we felt any loss in chlorine.

A paper presented on October 31, 1939, at the North Carolina Section meeting at Greensboro, North Carolina, by P. W. Frisk, Manager of Chemical Laboratories of the American Enka Corp, Enka, N. C., and by A. J. Conrad, Chemist, Laboratories of the American Enka Corp.

These tests for chlorine were carried out in conjunction with our bacteriological tests and, since we checked our raw water, settled water, and filter effluent water, we were able to know at all times whether we were obtaining sterilization.

This brought us to the point of carrying out a series of laboratory tests where we could very carefully combine, control, and analyze the results.

The chlorine and ammonia treatment for water to form chloramine appears to have established a definite place in water purification. The most widespread application can be found recorded in a recently tabulated Bibliography and Abstracts on "The Chloramine Treatment of Water," collected and prepared by Project 465-97-3-35, U. S. Works Progress Administration for the City of New York, sponsored by the Department of Sanitation for New York City.

There seem to be some opinions that residual ammonia above the ammonia available for chlorination may be estimated by nesslerization.

In order to obtain definite proof on whether this is so, we carried out a few laboratory experiments, in which we could control the exact quantity of ammonia and chlorine.

We assume the reactions under our working conditions to be as follows:

The preparation of the solution

with Cl_2 and $H_2O \rightarrow HOCl$ and HCl

$HOCl + NH_3 \rightarrow NH_4OCl$

$NH_4OCl = NH_2Cl$ and H_2O

The above reaction has produced a monchloramine compound, which we will deal with in our experiments.

The first set of solutions consisted of solutions in which the chlorine was kept constant and the ammonia content varied from a ratio of 1:0.5 to 1:3.0. The ammonia water solution was tested by direct nesslerization and the HOCl acid solution prepared by liberating chlorine and absorbing in ammonia-free distilled water (see table 1).

The pH of the solution was increased with N/10 Na_2CO_3 before the chlorine was added. The pH as shown in table 1 was the final pH after both chlorine and ammonia had been united.

A second series of tests was made keeping the ammonia constant and varying the chlorine content from 1:0.5 to 1:1.8. (See table 2.)

The pH on the first six solutions was increased by adding N/10 Na_2CO_3 before adding the chlorine, which brought the pH to 8.

In solutions 7–12, the pH was increased after the combination of chlorine and ammonia. The pH of ammonia-free water was 6.2.

A third series of tests was made using the solutions as shown in table 3.

TABLE 1

SOLUTION NO.	Cl	NH_3	RATIO Cl/NH_3	NH_3 FOUND*	pH
	p.p.m.	*p.p.m.*		*p.p.m.*	
A	0.5				3.65†
1	0.5	0.25	1/0.5	0.19	6.9
2	0.5	0.50	1/1	0.49	7.5
3	0.5	0.75	1/1.25	0.73	7.9
4	0.5	1.00	1/2.0	0.97	8.2
5	0.5	1.25	1/2.5	1.25	8.2
6	0.5	1.50	1/3.0	1.55	8.5
7	0.5	None			6.9

* Found back by nessler test.
† 0.5 p.p.m. chlorine only.

TABLE 2

SOLUTION NO.	NH_3	Cl	NH_3 FOUND*	RATIO	pH AFTER REACTION
	p.p.m.	*p.p.m.*	*p.p.m.*		
A	0.5				6.9†
1	0.5	None	0.52		7.9
2	0.5	0.25	0.52	1/0.5	7.8
3	0.5	0.50	0.51	1/1.0	7.6
4	0.5	0.75	0.49	1/1.5	7.2
5	0.5	1.00	0.49	1/1.2	7.0
6	0.5	1.25	0.41	1/2.5	6.9
7	0.5	1.50	0.29	1/3.0	7.2
8	0.5	2.00	0.24	1/4.0	7.2
9	0.5	2.50	0.17	1/5.0	7.2
10	0.5	3.00	0.06	1/6.0	7.2
11	0.5	3.50	0.00	1/7.0	7.1
12	0.5	4.00	0.00	1/8.0	7.2

* Found back by nessler test.
† 0.5 p.p.m. NH_4OH only.

This third series of tests was carried out several times and each time we were able to confirm our results.

The ammonia-free water was oxidized with bromine water, boiled, and re-distilled.

TABLE 3

SOLUTION NO.	NH_3	Cl	RATIO	NH_3 FOUND	pH
	p.p.m.	*p.p.m.*		*p.p.m.*	
1	2.0	1.0	1/2.0	2.06	8.0
2	2.0	6.0	1/3.0	1.43	5.8 Below
3	2.0	None		2.06	8.5
4	None	6.0		None	5.8 Below

(1) Solution containing a definite excess of ammonia.
(2) A solution containing a definite excess of chlorine.
(3) A solution containing only ammonia.
(4) A solution containing only chlorine.

Interpretation of Results

1. Apparently, the chlorine and ammonia will give residual ammonia on nesslerization when combined at a ratio below 1:7.

2. The pH of the combined solution from 2.0 to 8.5 appears to have no effect on the decomposition products giving ammonia.

3. When the ratio of the chlorine and ammonia is greater than 1:2.5 the ammonia found back decreases very rapidly.

4. It is not reliable to attempt to determine the amount of uncombined ammonia present in solution of ammonia-chlorine when the ratio is below 1:7.

Conclusion

From the work which we have carried out, it appears that it is necessary to carry on a great many more experiments under various pH conditions and ratios of chlorine and ammonia. We consider this a progress report on this subject, therefore further work will be carried out on this problem.

Dust Filters for Flue Gas for Carbonating

By M. Udwin

FOR the greater part of the year clarification of Vaal River water is effected at the Rand Water Board's plant at Vereeniging by primary treatment with lime (approximately 5 grains of calcium oxide per gallon) followed by about 7 hours sedimentation. In a secondary treatment aluminium sulfate (containing 17.5 per cent of aluminium oxide) is added at a rate of from 0.8 to 2 grains per gallon and the water is again subjected to about 7 hours sedimentation before passing to a bank of rapid gravity filters.

When the water leaves the primary sedimentation basins it is markedly alkaline (hydrogen ion concentration or pH value is from 10.2 to 10.6). The alkalinity of the water to methyl orange is always higher than the alkalinity to phenolphthalein, but twice the latter considerably exceeds the former. The water, therefore, contains carbonate and hydroxide and is too caustically alkaline to be put into supply. The water is supersaturated with calcium carbonate and by the action of the carbon dioxide of the air on the hydroxide more calcium carbonate would be formed and the water would cause heavy deposits in the reticulation system and in hot-water installations.

For these reasons it is necessary to reduce the alkalinity and the reduction is carried out by means of carbon dioxide. The carbon dioxide is introduced into the water at the point where the solution of aluminium sulfate is added and the alkalinity of the water after treatment is due to bicarbonate (with only a trace of carbonate); in this condition a good coagulum of aluminium hydroxide can form and the water is so stabilized that material deposition of calcium carbonate will not take place in the pipelines.

The amount of carbon dioxide required varies with the variable daily demand for water and with the pH value of the water from

A paper contributed by M. Udwin, B.Sc., M.Inst.C.E., M.I.Mech.E., Chief Engineer, The Rand Water Board, Johannesburg, Transvaal.

which and to which this value is to be reduced. Formation of aluminium hydroxide coagulum is effected in the range of pH value between 8 and 8.4.

The amount of carbon dioxide required is obtained from the alkalinity to phenolphthalein (expressed as an equivalent of calcium carbonate) of the water to be treated and from the quantity of water to be treated. If the alkalinity is stated in parts per 100,000, the weight of carbon dioxide required per million (Imperial) gallons, after allowing for a 25 per cent loss of absorption, is:

$$\text{alkalinity} \times 110 \text{ lb.}$$

The works at Vereeniging are at an altitude of about 4,725 ft. and at ordinary temperature here 1 lb. of carbon dioxide measures about 10.2 cubic feet.

Carbonation with Flue Gas an Established Practice

The Board's practice for many years has been to utilize the flue gases from its boiler plant to supply the necessary carbon dioxide for carbonation. This practice though economic from the point of view of prime costs, since it utilizes waste gases which would otherwise be exhausted to the atmosphere, introduces the difficulty of removing the solid impurities in the flue gases before they can be handled by the blowers and delivered to the carbonation chambers.

The coal used at the works is of relatively poor quality. Its proximate composition averages:

Moisture	7 per cent
Volatile hydrocarbons	26 per cent
Fixed carbon	45 per cent
Mineral ash	22 per cent

and it contains about 1.2 per cent of total sulfur. The air-dried coal has an average calorific value of 9,380 B.t.u. Under the conditions in which the coal is burned the ash clinkers moderately well.

The flue gas which has passed through an economiser is drawn for use from near the bottom of the chimney.

The first plant installed by the Board to clean the flue gases consisted of six, circular, concrete-lined vessels approximately 6 ft. in diameter by 8 ft. high. Gas entered the first vessel (ash separator) through a downcast pipe in the center and then flowed vertically up

and down past two concentric baffles before it reached the outlet pipe. In this vessel the inner baffle was sprayed with water and consequently the gas was forced to pass through a curtain of water which was intended to remove the heavier fly ash and other solid matter in the gas.

From the ash separator the gas passed through two scrubber vessels fitted with timber trays on which coke was spread to a depth of about 4 inches. A water spray washed the gas on its upward passage through the layers of coke.

The scrubber vessels were duplicated so that two of them could be put out of service for cleaning purposes.

The final stage of the gas cleaning was performed in the dryer vessel fitted with trays similar to those in the scrubbers on which wood wool (excelsior) was loosely packed.

The lower end of each of these vessels was closed with a water seal into which the grit and soot were washed and eventually discharged to a sludge main.

Large Gas Scrubbers Built

After a short period the water purification plant was extended and it was found that this gas scrubber was too small for the quantity of gas required and a larger set of scrubbers designed on the same principle of operation was erected. These consisted of two rectangular concrete chambers about 16 ft. square and 17 ft. high fitted with trays containing coke; spray water was introduced from the sides and the gas was scrubbed while passing through these trays.

From the scrubber chamber the gas passed through a concrete, coke-filled downcomer 2 ft. by 3 ft. in section leading into a dryer chamber 10 ft. by 4 ft. 4½ in. and 13 ft. 9 in. high. This chamber was fitted with trays containing wood wool through which the gas passed vertically upwards and was finally exhausted to the blower suction through a 9-inch pipe with a ½-inch concrete lining.

As the gas contained sulfur dioxide a layer of manganese peroxide (pyrolusite) was placed in the lowest tray of the scrubber in order to oxidize the sulfur dioxide to sulfur trioxide which would be more readily absorbed in the scrubber than was the sulfur dioxide. This was not entirely successful as it was found that the sulfur trioxide (or sulfuric acid) formed passed through the scrubber as a mist and was retained in the deposit which collected in the blower (referred to below).

Both of the gas cleaning plants previously described suffered from the following defects:

1. They were difficult to maintain in a clean, working condition.
2. A considerable amount of the wet ash and soot passed through into the blowers.
3. The wet scrubbing process led to the gas entering the blowers in a saturated condition.

As a result of these latter two defects the gas passages and the impellers of the turbo blowers became choked with fine grit in a damp condition. This choking up of the blower was naturally accompanied by a falling off in the pressure and output of the blowers, and experience showed that it was necessary to dismantle each blower completely after 5 to 7 working days, and remove the accumulation of grit from the gas passages.

In addition to the above mentioned disadvantages, which entailed considerable maintenance costs, the moisture entering the compressor was found to accumulate in the gas pipes leading to the carbonation chambers.

This liquid, like the deposit in the blower, was very strongly acid (sulfuric) and to avoid rapid corrosion of the mains and delivery pipes these were lined with concrete. The accumulation of a strongly acid liquid in the pipes rendered it necessary to fit the gas delivery pipes to the carbonation chamber with glass-lined rubber diaphragm valves.

In order to overcome the disadvantages and difficulties which have been mentioned, it was decided to attack the problem of gas cleaning from an entirely different point of view and an attempt was made to design a gas filtering plant which would fulfil the following requirements:

1. Completely eliminate the gritty and heavier particles of ash before the gas entered the blower.
2. Eliminate soot and fine particles of ash to the maximum practical extent.
3. Reduce the gas temperature from that at the chimney to the point where it entered the blower, in order to get high duty from each machine.
4. Prevent moisture entering the blower and ensure that the gas should not be cooled down to the dewpoint.
5. Make the plant self cleaning when in operation and easily accessible for inspection.
6. Keep the friction resistance as low as possible so as not to reduce the blower delivery pressure and output.

In addition to the requirements enumerated above it was also necessary to consider the compactness of the plant installed and the design had to be such that the whole could be manufactured locally and from materials which could be readily replaced.

To meet the necessary requirements it was first decided to treat the gas in a dry condition and to rely on the exposed surfaces of the pipes, vortex and bag filters to give the necessary cooling effect.

It was also decided to carry out the separation of the solid matter in two stages and with this object in view a downcast vortex separator was installed in series with a bag filter.

The vortex was designed to remove the coarse gritty particles which were carried over from the stack and the bag filter was intended to extract the smaller particles which passed through the vortex.

It was realized that the dry removal of the solid matter from the gas would leave the gas charged (up to about 0.2 per cent) with sulfur dioxide. This was a matter of little moment since the amount of sulfite formed in the water would be insignificant and would probably be oxidized to innocuous sulfate by the time the water reached the filters and any sulfite which passed the filters would be converted by the chlorine subsequently added to the water. Careful examination has failed to show any ill-effect from sulfur dioxide.

In the initial stages an experimental plant consisting of one vortex and a single cell bag filter was installed in order to test the suitability and efficient operation of such an installation before a complete plant was put into operation.

After the experimental filter plant had been in operation for one week the blower was opened up for inspection and it was found to be perfectly clean and free from grit or other deposits; the blower was therefore put back into service again and was run continuously for 52 days, after which period it was again opened up for inspection and found to be in a comparatively clean and satisfactory condition from an operating point of view.

During this period the operation of the vortex and bag filters were closely observed and it was found that a considerable quantity of coarse grit was extracted by the vortex and also that a commensurate quantity of very fine soot and grit was extracted by the bag filter. It was further found that the discharge of the extracted grit from the vortex and the bag filters was easily performed and did not in any way affect the continuous operation of the blower.

Design and Construction Outlined

The design and construction of the vortex separator can be seen in fig. 1. It consists of a cylindrical shell (A) with a flat ribbed top cover plate (B) and a conical bottom (C). The flue gas enters the upper portion of the shell through the rectangular tangential branch (D). A conical deflector plate (E) is suspended from the top cover by means of a short length of pipe. The gas thus acquires a circular motion at high velocity and the heavier particles of grit, etc., are thrown against the side of the cylinder and subsequently fall into the conical bottom.

The flue gases, to which a spinning motion has been imparted, are sucked into the outlet branch (F) thus forming a vortex. The lower end of the cone is sealed by means of a sliding plate valve (G) which is opened periodically to allow the accumulated grit to be discharged into the dust box (H) from which it is shovelled and removed to the depositing site.

The arrangement of a typical bag filter can be seen in figs. 2 and 3. The flue gases enter the 12-inch inlet manifold (J) and pass into the pyramidal dust hopper (K) whence they pass upwards into the inside of the flannel filter bags (L) where the finer particles of dust are deposited. The filtered gases then leave by way of the 12-inch downcomer and enter the outlet manifold (M) which is directly connected to the suction side of the blowers.

It will be noticed that the bags are secured at their lower ends by clamps to ferrules in the division plate at the top of the dust hoppers and at the upper ends they are clamped to sheet metal end pieces which are suspended from the supporting frame (N). This frame is slung on springs from the casing of the bag filter and the whole frame and bags can be agitated by hand by means of a steel cable (P) which passes through the casing at the side remote from the inlet and outlet manifolds.

It was found advisable to agitate the bags periodically thus shaking the accumulated dust into the dust hopper. When it is required to extract this dust the slide valves on the inlet and outlet manifolds are temporarily shut and compressed air at low pressure (8 lb. per sq.in.) is admitted into the bag filter casing by means of a hand controlled valve. This air causes a blow back through the bags and liberates the finer particles in the filter material and also gives sufficient pressure to blow out the accumulated dust in the pyramidal

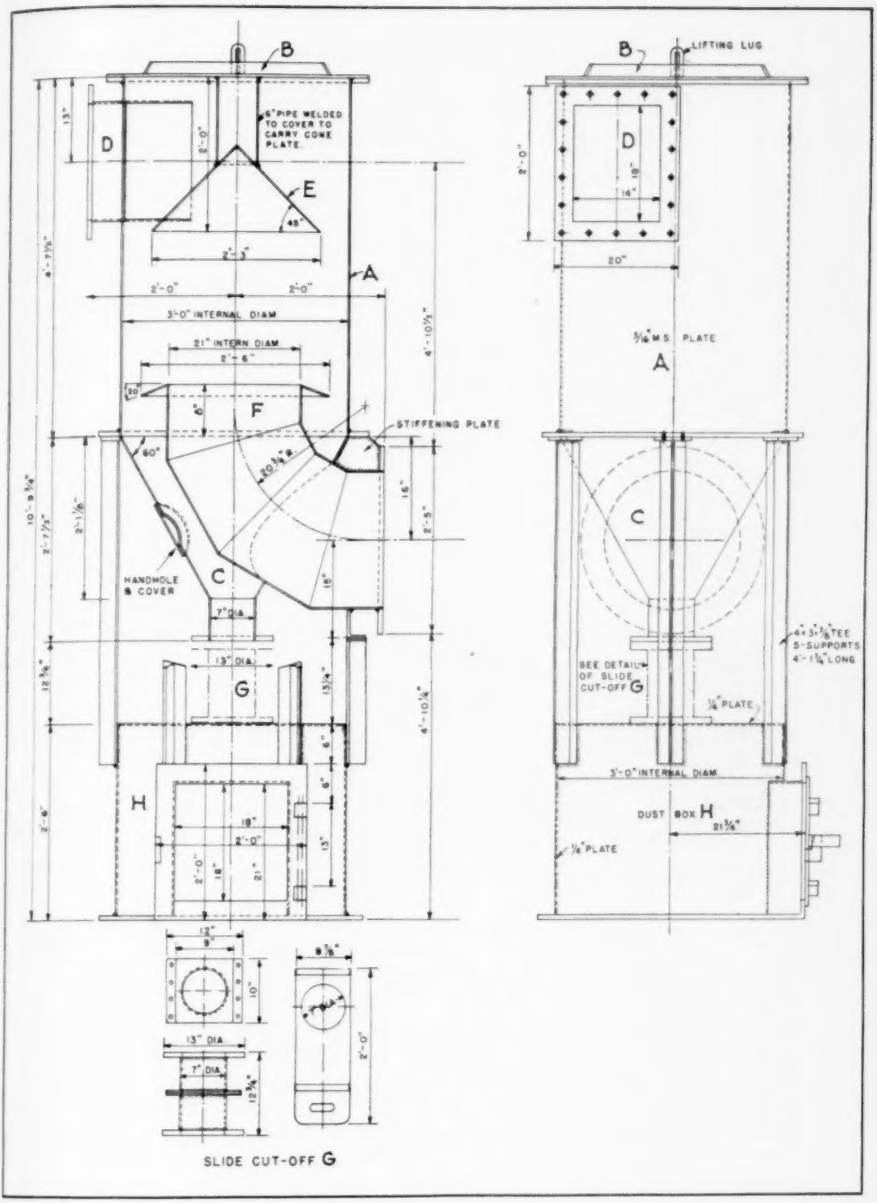

FIG. 1. Rand Water Board Vortex Type Dust Separator for Carbonation Plant at Vereeniging.

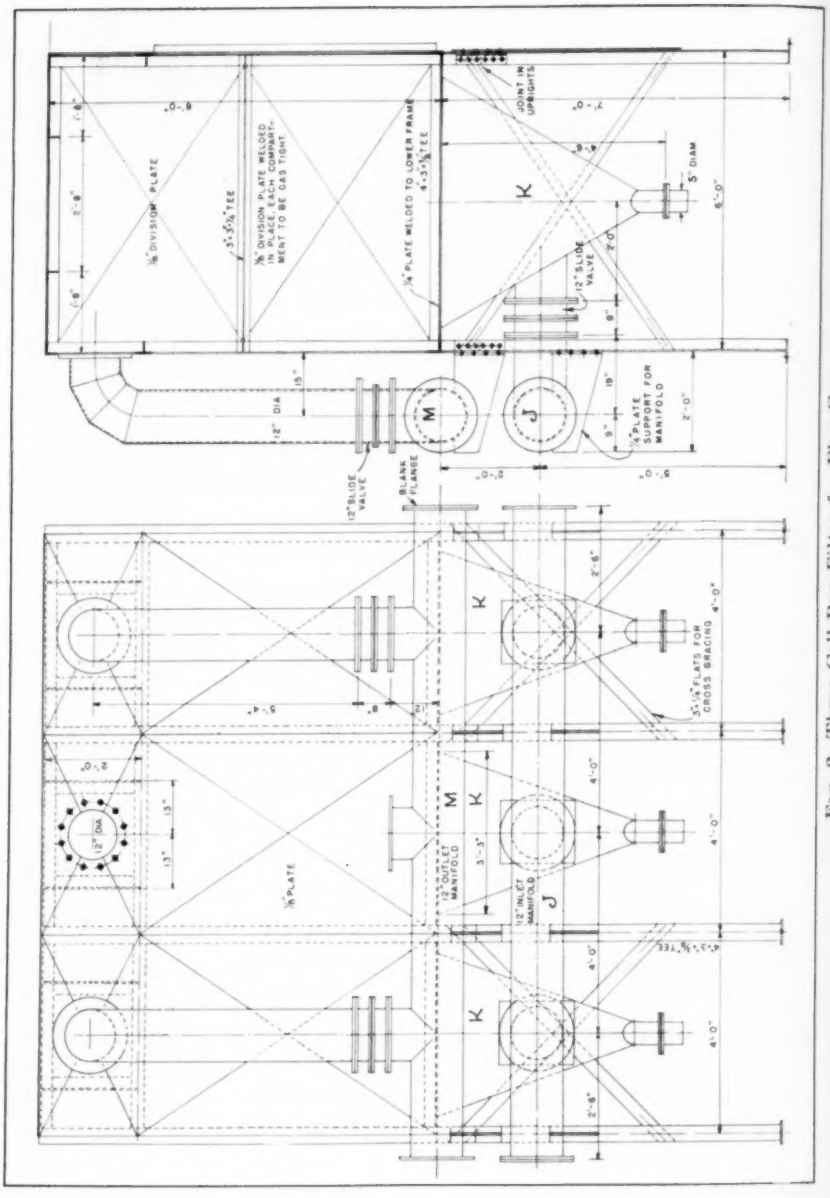

Fig. 2. Three-Cell Bag Filter for Flue Gas

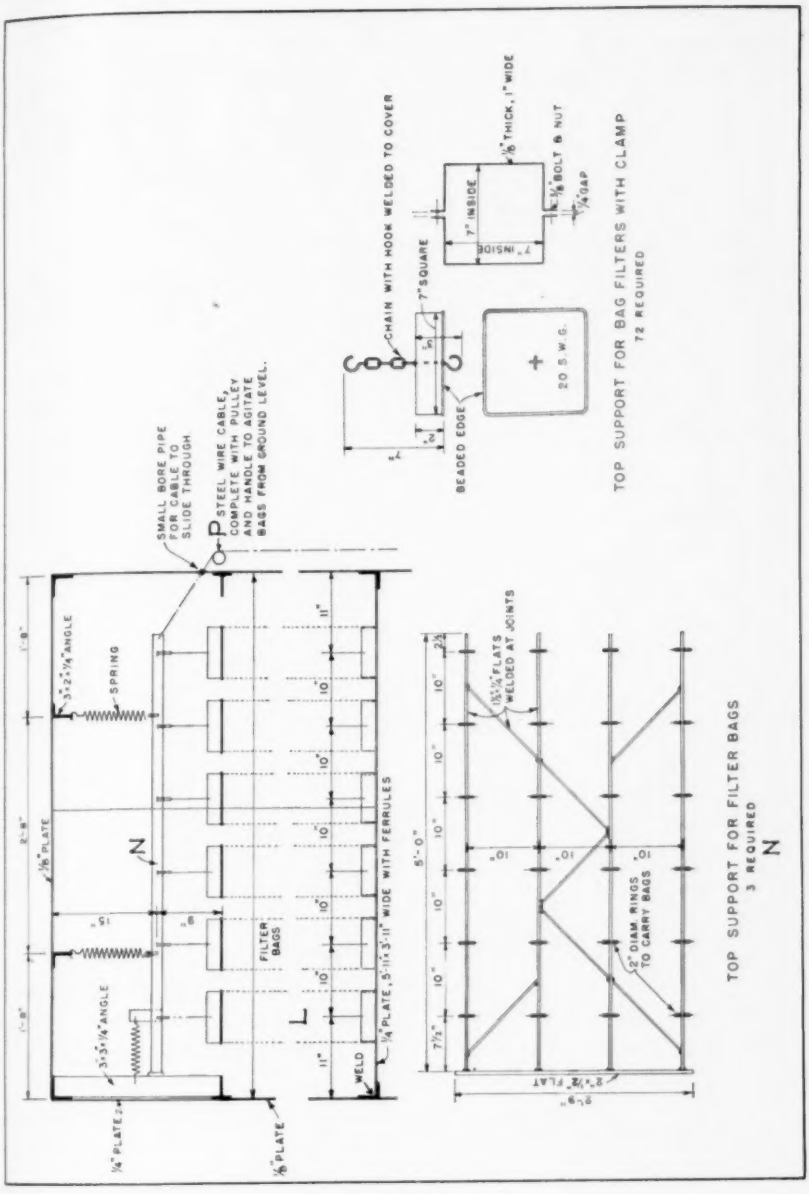
SMALL BORE PIPE FOR CABLE TO SLIDE THROUGH
STEEL WIRE CABLE, COMPLETE WITH PULLEY AND HANDLE TO AGITATE BAGS FROM GROUND LEVEL.
CHAIN WITH HOOK WELDED TO COVER
7" SQUARE
BEADED EDGE
20 S.W.G.
TOP SUPPORT FOR BAG FILTERS WITH CLAMP
72 REQUIRED
⅛" THICK, 1" WIDE
7" INSIDE
⅜" BOLT & NUT
SPRING
FILTER BAGS
¼" PLATE, 5"×3½" WIDE WITH FERRULES
WELD
⅛" PLATE
¼" PLATE
⅛" PLATE
1½"×1½"×¼" FLATS WELDED AT JOINTS
2" DIAM. RINGS TO CARRY BAGS
TOP SUPPORT FOR FILTER BAGS
3 REQUIRED

FIG. 3. Arrangement and Supports for Filter Bags

hopper. One cell only is put out of operation and the cells are cleaned in rotation.

The filtering material used for the filter bags is a pure wool weighing $5\frac{1}{4}$ to $5\frac{1}{2}$ oz. per yard 30 inches wide—warp 40 to 41 threads per inch, weft 44 to 46 threads per inch, and the seams are double sewn with strong woolen thread. The first bags used were sewn with cotton thread but this was found to perish very rapidly.

In the experimental bag filter eleven bags each 6 ft. long by 9 in. in diameter were employed. Allowing 2 inches for clamping at each end of the bag the effective area per bag equals 13.35 sq.ft. and the total area, therefore, was 147 sq.ft.

Observations taken on this experimental plant when working in conjunction with one blower whose rated capacity was 1,800 cu. ft. per minute gave the following data:

1. Suction at blower inlet flange = 0.55 in. Hg or 0.27 lb. per sq.in.
2. Blower delivery pressure (by gauge) = 5.2 lb. per sq.in.
3. Total pressure across blower = 5.47 lb. per sq.in.
4. Gas temperature entering vortex = 241°F.
5. Gas temperature entering bag filter = 204°F.
6. Gas temperature leaving bag filter = 175°F.
7. Gas temperature at blower suction = 140°F. (dry bulb)
8. Gas temperature at blower suction = 99.5°F. (wet bulb)
9. Gas temperature at blower delivery = 246°F.

The dew point of the gasses corresponding to items 7 and 8 is 90°F.

As the original experimental unit had proved to be satisfactory in operation it was decided to extend the plant and consequently two vortex separators each connected to a separate 16-inch pipe direct from the stack were installed.

From these vortex separators the gases were taken through three bag filter cells connected in parallel by means of their inlet and outlet manifolds; the filtering area was thus increased and as the two later cells contained 18 bags each the total filter area became 627 sq.ft.

Subsequently a further extension consisting of one vortex separator

and a three-cell bag filter was added to the installation. In this case the bags are arranged on a wire frame of square cross section (side, $7\frac{1}{4}$ inches) as shown on fig. 2 and each cell contains 24 such bags giving a filtering area in the three cells of 986 sq.ft.

The total flannel filtering area available is 1,613 sq.ft.

The filtering installation is so arranged that it can be used with any blower or with any combination of blowers and the results given in table 1 show that the system satisfactorily fulfils its purpose.

The blowers at present installed at the Board's Vereeniging Station consist of the following units:

Nos. 1 & 2. Two stage Reavell Turbo Blowers each capable of handling 1,800 cu.ft. of the gas per minute at 95°F. and a barometric pressure of 25.5 inches Hg; Delivery pressure $5\frac{1}{2}$ lb.per sq. in. when running at 9,700 r.p.m.; Coupled through the medium of double helical speed increasing gears manufactured by David Brown & Sons to a Crompton Parkinson Induction Motor having a continuous rating of 68 h.p.

No. 4. Single Stage Reavell Turbo Blower capable of handling 3,260 cu.ft. of flue gas per minute at 95°F. and a barometric pressure of 25.5 inches Hg; Delivery pressure $4\frac{1}{2}$ lb.per sq.in. when running at 10,000 r.p.m.; Coupled through the medium of double helical speed increasing gears manufactured by David Brown & Sons to a Laurence Scott 120 b.h.p. motor.

A brief description of the methods employed to diffuse the gas at the points of carbonation will no doubt be of interest as this has also been the subject of a considerable amount of experimentation.

The earliest type of gas distributor consisted of a rectangular grid of pipework. The outer rectangle of the grid consisted of a 3-inch brass pipe and between the longer sides of the grid, brass condenser tubes were arranged in parallel. These condenser tubes had $\frac{3}{32}$-inch holes drilled on their under sides at 4-inch centers. The gas from the blowers entered each distributor by means of a 4-inch downcomer pipe. It was realized that these pipes could not form the permanent arrangement owing to corrodability but the manifold served for experimental purposes.

The first permanent scheme of conducting the gas into the water used distributing pipes made of glazed stoneware of 4 inches internal diameter. Brass Candy Patent Gas Nozzles were fitted at 12-inch intervals along these pipes. The whole of the pipe reticulation was

TABLE 1

Results from Filtering Installation

1.	Bag Filter Cells in use	Old	Old	Old & New	Old & New	Old & New	Old & New	Old*	New*
2.	Blowers in use: Nos.	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	4	2
3.	Suction at Blower Inlet in. Hg	0.827	0.867	0.591	0.473	0.355	0.236	—	0.394
4.	Blower Delivery Pressure in. Hg	10.2	10	10.16	10.32	10.42	12.2	9.25/9.85	10.95
5.	Total Pressure across blower in. Hg	11.027	10.867	10.751	10.793	10.792	12.436	—	11.344
6.	Total Pressure across blower lb. sq. in.	5.41	5.33	5.28	5.3	5.3	6.1	4.54† to 4.83	5.57
7.	Gas Temp. entering Vortex °F.	—	—	190	183	175	168	175	189
8.	Gas Temp. leaving Vortex °F	—	—	183	175	170	158	161	181
9.	Gas Temp. leaving bag Filter °F.	137	143	150	139	140	126	125	144
10.	Gas Temp. blower suction (wet bulb)	97.2	99	96.8	98.2	98.6	98.8	—	101.8
11.	Gas Temp. blower suction (dry bulb)	132	141	144	128	128	126	—	144
12.	Gas Temp. blower delivery °F.	208	219	220	199	208	211	—	208
13.	Suction Loss across bag filter in. Hg.	0.377	0.421	0.241	0.151	0.139	0.058	0.075 to 0.098	0.133
14.	Dew Point of gas from Items 10 and 11, degrees F.	90	90	86	92	93	94	—	93

NOTES: All suction readings referring to the blowers are taken on the No. 2 blower.

The quantity of grit extracted during a period of 6 days is:

From the Vortex = 815 lb.

From the Bag Filter = 707 lb.

This quantity was extracted during the time when the 2 small blowers were running (each rated at 1,800 cu.ft. per minute).

Filtering Area—Old Bag Filter 47 bags 9 inches diameter. Total Filter Area = 627 sq.ft.

Filtering Area—New Bag Filter 72 bags 7¼ inches square. Total Filter Area = 986 sq.ft.

* The suctions and delivery of each blower isolated from each other.

† Delivery Pressure only.

set in mass concrete which was of sufficient depth to permit the nozzles to project. This distributor was a decided improvement on the earlier type, but here again the corrosive action of the gas caused trouble and the nozzles required occasional replacement.

In the next series of sedimentation tanks which the Board put into service the distribution of the gas was similar to the installation previously described except that inverted pyramids containing balls of glazed earthenware, on the lines of the Wheeler filter floor, were substituted for the Candy nozzles previously employed and, further, the whole of the floor of the carbonation chamber was covered with a layer of smooth round pebbles. This arrangement has not proved very satisfactory inasmuch as it is well-nigh impossible to obtain an even distribution of the gas over the whole area.

In the most recent arrangement for bubbling the gas through the water glazed earthenware, pipes are arranged in trenches; each 24-inch length of pipe has a $\frac{1}{4}$-inch hole in it and the pipes are laid so that the holes are on the bottom side of the pipes. The top of the trench is covered with porous Alundum Plates 12 in. by 12 in. by 1 in. thick through which the gas percolates evenly over the whole length of the trenches. This latter method of carbonation has now been in service for two months and is giving a very good distribution of the gas; it is too early to say whether these plates will prove successful over a lengthy period as the plates may choke. Investigations are being made to obtain the Candy filter nozzles in stainless steel as it is felt that ultimately this method of gas distribution will prove the most successful.

The quantity of gas blown through the water is adjusted so that the pH value of the water is reduced to the required point within the range of 8 to 8.4.

The pH value of the water, about 2 minutes after it passes the carbonation chamber, is recorded by means of antimony electrode pH measuring instruments.

The bubbling of filtered flue gas through the water imparts no taste or odor to the water.

The experimental and design work involved in developing the above scheme was carried out by the Board's staff, and in this connection acknowledgment is made to Messrs. J. P. Leslie, B.Sc., M.Inst.C.E.; J. McCrae, Ph.D.; T. Breslin, A.M.Inst.C.E., A.M.Am.Soc.C.E.; and R. W. Kewley, M.Eng., A.M.I.Mech.E.

* The suctions and delivery of each blower isolated from each other.
† Delivery Pressure only.

Addendum Giving Measurement of Solid Matter

The Physicist to the Transvaal Chamber of Mines (Mr. H. S. Patterson, B.Sc.) has been kind enough to determine the quantity of solid material in the flue gas after it has been drawn through the cleaning plant. Using a thermal precipitator it has been found that one cubic centimeter of the gas carries about 65,000 particles. The size distribution of the particles has been evaluated and it was found that approximately half of them had a mean diameter of less than 0.2 micron. Particles of mean diameter 0.2 micron accounted for 40 per cent of the whole and particles of over 1 micron diameter constituted only 0.7 per cent. The largest particles present had a diameter of 2.5 microns.

By ignition about 99 per cent of the particles were removed; they were, therefore, either carbon or of a carbonaceous type.

On the assumption that the particles have a cubic form the volume occupied by the solid particles in one cubic centimeter has been computed to be 1.53×10^{-9} cubic centimeter and if their density be assumed to be 2 the weight would be about 3×10^{-9} gram. The weight of the solid matter suspended in a cubic foot of the cleaned gas would be approximately 9×10^{-5} gram and a million cubic feet would carry about 90 grams (very roughly, quarter of a pound).

The gas handled by the plant contains, on the average, about 0.2 gram of suspended solid matter per cubic foot; a million cubic feet, therefore, contains between 400 and 500 pounds of solids.

These figures illustrate the high efficiency of the installation in removing solid matter (ash and soot) from the flue-gas.

Water Supply Safety Control

British Ministry of Health Memorandum

Water Supplies—Circular 1684

THE Minister of Health feels it incumbent upon him, in the light of recent experience, to remind water undertakers of the serious responsibility which rests upon them in relation to the purity of the public water supplies which they control.

It is the statutory duty of all Local Authorities operating under the Public Health Acts to ensure that water supplied by them to consumers is at all times wholesome, and a like responsibility is expressly placed by Parliament upon water undertakers, whether Local Authorities or Statutory Companies, who derive their powers from special statutory enactments.

The relative immunity from serious outbreaks of water-borne disease that the country has long enjoyed must not be allowed to obscure the paramount importance of taking all possible steps to ensure that this responsibility is adequately discharged and every practicable precaution adopted to safeguard the purity of supplies. The machinery and methods of control, which must necessarily vary with the circumstances of different undertakings, are matters for the decision of the responsible authorities themselves, but it will be realised that the first necessity is that the undertaking should be

EDITOR'S NOTE: With the objective of making available to the members of the American Water Works Association and the readers of its Journal, two documents issued by the British Ministry of Health are herewith reproduced by permission of the Executive Officer thereof. The first—Circular 1684—was issued on March 12, 1938 and addressed to the Clerks of the Municipal Councils or Boards and to the Secretaries of the various Water Companies within the Ministry's jurisdiction. The second—Circular 1771—was issued on January 30, 1939 and similarly addressed.

It is the Editor's opinion that the preparation of these statements was stimulated by the Croydon typhoid outbreak of 1938 to which reference was made by abstract in this JOURNAL in vol. 30 on pages 852 and 1242. The documents are so closely related to certain water supply activities in North America and certain material published in this JOURNAL that the wisdom of their duplication is clearly indicated.

under the supervision of a qualified engineer who, in the case of the larger undertakings owned by Local Authorities, should be a chief officer of the Authority directly responsible to the appropriate Committee, and in all cases should be in a position to give detailed personal attention to the work. The Minister has no doubt that water undertakers generally will appreciate the need for maintaining the high standards of administration which are rightly demanded in a matter of such fundamental importance to public health, but the results that may ensue from neglect of precautionary measures are so serious that the Minister regards it as his duty, at the present time, to impress upon all water undertakers the imperative need for unremitting care in the supervision of the water supplies for which they are responsible.

Where water is being supplied without treatment, the water undertakers must satisfy themselves that this practice can safely be continued. For this purpose, they should keep a constant watch on the quality of the water by frequent analyses. How often the analyses should be made in a particular case depends on local conditions, e.g., on the character of the source and of its gathering ground and their position in relation to each other. The Minister is satisfied that under modern conditions more frequent analyses are needed in many cases as a minimum precautionary measure, particularly where there is a tendency to fluctuation in the composition or bacterial content of the water. The water undertakers should be guided as to the frequency of analyses by the views of their expert advisers after examination of the local conditions. It is not sufficient, however, to rely on results from analyses alone. Regular and frequent inspections should be made of the area forming the gathering ground of any spring or stream used as a source of supply and of areas surrounding underground sources of supply situate in or near the outcrop of the strata from which the water is drawn, and all practicable steps should be taken to remove possible sources of contamination in these areas. If, as a result of their analyses and inspections or for any other reason, the water undertakers have cause to think that any of their sources of water supply cannot be made and kept free from liability to pollution, they should immediately treat the water by effective methods of purification.

In a separate communication* to the water undertakers concerned, particular attention is being drawn to the need for special safeguards where water is supplied from wells or borings into the chalk or limestone at or near the outcrop of those formations.

* Circular No. 1771, which follows.

Where the water is treated, the treatment should as far as possible be automatically controlled, and where the treatment includes chlorination, the dosage should be automatically and continuously recorded. The efficacy of any form of treatment given should be verified by frequent tests of the treated water. The method, extent and control of treatment required in any particular case are also matters on which the water undertakers should be guided by expert advice. Periodic analyses should be made of the raw water in order to keep a check on any change in its character and on the treatment needed. The Minister would, however, stress the point that treatment of the water should be regarded, not as a complete security in itself, but as complementary to the taking of all practicable steps to seek for and remove the causes of pollution of the raw water.

The utmost vigilance is also required to ensure that no risk of contamination of the water supplies arises from operations in connexion with the normal maintenance and improvement of waterworks, such as extensions of the works, the reconditioning of wells, reservoirs, and filters, the repair of pumping plant, etc.; and in some cases, e.g., where men are engaged on work in a well, it is essential either to cut off the supply from the well until the work is completed or to give precautionary treatment to the water.

The Minister would emphasise that the administrative responsibility for a service of such vital importance to health can only be successfully discharged if there is effective collaboration and co-operation between those responsible in their various capacities for the conduct and efficiency of the undertaking and between the water undertakers and the Local Authorities of areas served by them. It is essential that Local Authorities who are themselves water undertakers should ensure that the Water Committee and its officers work in close co-operation with the Public Health Committee and the Medical Officer of Health. Where the water undertakers are not the Local Authority for an area supplied by them, they should always be ready, on request, to furnish full information to that Local Authority or its Medical Officer of Health as to the quality of the water supplied and the precautions taken to safeguard its wholesomeness. On the other hand, Local Authorities should make it their duty to bring to the notice of water undertakers cases of enteric fever or other diseases likely to be water-borne, and also any building development or other operations in the Local Authority's area which might affect the purity of a source of water supply. . . .

Safeguards in Administration of Water Undertakings

Circular 1771

General

1. The prevention of water-borne diseases was the chief and almost the only concern of sanitation as it was understood a hundred years ago. Recent events have shown that even now it can be achieved only by careful and constant supervision of supplies of drinking water. Between 1911 and 1937 there occurred 21 outbreaks of disease, conveyed by public water supplies, of such gravity as to merit detailed mention in the annual reports of the Medical Officer of the Local Government Board and the Chief Medical Officer of the Ministry of Health. Pollution prior to storage and distribution was responsible for 13 of these outbreaks, four of the 13 involving overground supplies and nine of them underground supplies. Pollution during storage occurred in two cases. Pollution during distribution appears to have occurred in six instances. The numbers of known cases of disease resulting from these outbreaks were: enteric fever (including paratyphoid) 1,237; bacillary dysentery 2,800; and gastro-enteritis 7,439.

2. The Minister has brought* to the notice of all water undertakers the need for unremitting care in the supervision of the water supplies for which they are responsible. Particular stress was laid upon the importance of effective collaboration and co-operation between the various officers responsible for the conduct and efficiency of the undertaking and also between the water undertakers and the local authorities of areas served by them. The importance of this aspect of water administration is again emphasised.

3. The object of this memorandum is to draw attention to the precautions which should be taken in the day to day administration of water supplies. These precautions are no more than are already

* Preceding document.

recognised as good practice in water administration and water undertakers should carefully review their arrangements and take appropriate steps in the light of the circumstances of their undertaking to improve their practice where this is necessary.

4. There are in England and Wales some 530 local authorities and 15 joint bodies supplying water under the Public Health Acts, and 260 local authorities, 33 joint bodies and 173 water companies supplying water under powers given by Special Acts. Three-quarters of the population of the country is supplied with water obtained from overground sources—from rivers, streams and springs—and the remaining one-quarter from wells and borings into water-bearing strata. All the bodies referred to are under statutory obligation to provide wholesome water for the use of their consumers. The variety of sources and conditions is such that it is not possible to lay down any one method applicable to every case of ensuring the fulfilment of this obligation. Undertakers must have regard to the circumstances in their own areas, e.g., the nature and situation of the source from which the supply is drawn and the character and formation of the gathering ground, and must themselves decide, on competent advice, the machinery and methods of control which are most suitable to their own local conditions.

Health of Workmen Employed on Water Works

5. Careful discrimination should be exercised in the selection of workmen employed on waterworks other than works where no risk to the purity of the water supply is likely to arise, and the clinical history of each such workman, particularly with reference to enteric infection, should be thoroughly investigated in order to determine his suitability for this kind of employment. Any man attacked by illness associated with looseness of the bowels should be suspended from work until his recovery is complete and medical examination shows that he is safe to return to work. Every new man proposed to be employed on any part of the works where there is risk of his contaminating the water should be examined by means of a Widal test of his blood in order to ascertain whether or not he is likely to be a typhoid carrier. If a positive result is obtained which is not attributable to preventive inoculation, he should not be employed unless bacteriological examination of his excreta on at least three occasions shows negative results as regards the presence of pathogenic bacteria.

In the case of local authorities who are water undertakers, these examinations should be arranged for by their Medical Officer of Health, who will review all the circumstances and whose decision on the question of the employment or continued employment of any man for this kind of work should be final. The Medical Officer of Health or other expert medical adviser should be similarly consulted in the case of other water undertakers.

General Cleanliness of Water Works

6. All buildings, machinery, apparatus and yards used for waterworks purposes should be kept scrupulously clean. Proper and adequate sanitary accommodation and washing facilities should be provided at any part of the works where men are regularly employed. All such accommodation should be regularly inspected, and all drains should be periodically tested in order to ensure that no leakage occurs.

Protection of Sources of Supply

7. Whatever the source of supply may be, and whether or not purification treatment is given to the water before it is brought into service, every effort should be made to secure that so far as is practicable the raw water is protected from pollution.

Upland Overground Sources.

8. Where the source of water supply is a reservoir impounding the head waters of a stream or an intake near the source of the stream, the water undertakers should, wherever reasonably practicable, acquire the whole of the gathering ground above the reservoir dam or the intake, and protect the reservoir or intake by adequate fencing. Steps should be taken to secure that drainage from farmyards or houses remaining on the gathering ground or the manuring of land on the gathering ground does not pollute the source of supply.

9. Where it is not practicable to acquire the gathering ground and thus control it, it should be part of the routine duty of the water undertakers' staff to make regular and frequent inspections of the whole of the gathering ground with a view to detecting possible causes of pollution. Any building development on the gathering ground should be carefully watched for risk of contamination of the source of supply.

Springs.

10. Where the source of supply is a spring, a sufficient area of land surrounding the spring should be acquired by the water undertakers to enable them to apply adequate protective measures, and a close watch should be maintained by the water undertakers' staff over the area in the vicinity of the spring so that any possible source of pollution may be quickly detected.

River Supplies.

11. Where a supply is obtained from the lower reaches of a river or stream regular and frequent inspections should be made of the course of the river or stream above the intake with a view to ascertaining the likelihood of pollution being discharged.

Underground Sources.

12. A well or borehole forming a source of supply should be made watertight to such a depth as will prevent any surface pollution from entering, and there should be an efficient sealing between the casing of the borehole and the surrounding ground. Periodic inspections of wells and boreholes should be made in order to ensure that the lining is sound. The water undertakers should acquire a sufficient area of land surrounding the site of the well or borehole to enable them to protect the immediate surroundings. Where the well or borehole is on or near to the outcrop of the strata from which the water is drawn, it should be the routine duty of the water undertakers' staff to make regular and frequent inspections of the area within at least two miles of the site of the well or boring with a view to detecting possible causes of pollution. Particular attention should be paid to any cesspools and soakaways in such an area and the water undertakers should satisfy themselves that danger to their source of supply is not likely to arise from them. Further, a map showing details of any sewerage system within this area should be kept.

13. The inspections by the water undertakers' staff referred to in the preceding paragraphs should be carefully recorded and reports made to the water undertakers or their appropriate Committee. Each report should draw special attention to any alterations which have occurred on the gathering ground since the preceding report. Where the reports indicate a possible cause of pollution of the source of supply, the water and undertakers should take such action as may

be available to them to remove it. It will be appreciated that these reports will assist materially in interpreting the results of periodic analyses of the raw water.

Analyses

14. Where water is being supplied without treatment, the water undertakers should make frequent and regular analyses of the water in order to satisfy themselves that this practice may safely be continued. If there is a tendency to fluctuation in the composition or bacterial content of the water, or if inspection of the gathering ground of the source of supply shows possible risk of pollution, analyses should invariably be made at very short intervals. How frequently and at what times the analyses should be made must depend on local conditions and this question should be determined in the case of each water undertaking by the expert views of their advisers after consideration of the local conditions.

15. The results of any analyses must be read in the light of the nature of the source and the condition of the gathering ground, and it is not possible to lay down any hard and fast standard which would be applicable to all supplies. If, however, as a result of analyses and of the inspection of the gathering ground, the water undertakers, acting in the case of local authorities on the advice of their Medical Officer of Health and in other cases on the advice of their experts, have any grounds for suspecting that the water cannot be made and kept free from risk of becoming unwholesome they should not hesitate to subject the water to an effective method of treatment.

16. Where the water is treated it is important that regular analyses should be made of the raw water as well as of the treated water. It will not of course be necessary to make such frequent analyses of the raw water when treatment is given as when it is not, but the analyses should be of sufficient frequency to enable an adequate check to be kept on the character of the raw water as a guide to the treatment required.

Treatment of Water

17. The conversion of a polluted and therefore dangerous water into a safe potable water is a matter requiring the greatest care if the health of the consumer is not to be jeopardised. There is often a tendency to think that, provided arrangements are made for chlorination, safety is secured whatever the condition of the raw water. It

cannot be sufficiently stressed that a policy of reliance on a single line of defence between the consumer and a polluted source of water supply is fraught with danger. Not only should every effort be made, as has been suggested above, to keep the source as free as possible from pollution, but, wherever practicable, the method of treatment should be such as to provide at least two lines of defence, such as, for example, chlorination or other effective form of sterilisation after storage or filtration.

18. Treatment plant should at all times not only be under the supervision of properly trained persons, but should also as far as possible be automatically controlled. Where the treatment includes chlorination, the dosage should be automatically and continuously recorded. The dosage should also be such as to leave residual chlorine after a reasonable period of contact, the period required being determined by the undertakers on expert advice, and frequent tests should be made to ensure this.

Service Reservoirs

19. Service reservoirs from which water passes direct to the consumer should, wherever practicable, be covered. An open reservoir of this kind is dangerous, because any pollution entering it reaches the consumer in a short space of time, and if it is not practicable to cover it, the water should be adequately chlorinated as a safeguard.

Care should be taken to ensure that pollution cannot enter reservoirs through ventilators, manholes, washouts and overflows. Service reservoirs should be periodically inspected with a view to detecting any cracks or other defects which may develop and permit the access of pollution to the water.

Mains and Hydrants

20. All new mains should, after connection with the supply system, but before being used to convey water to consumers, be thoroughly flushed. Where possible chlorinated water should be used for this purpose. Mains that have been cut and repaired should be similarly treated.

The arrangement of air valves and air vents to mains should be such that there is no possibility of pollution entering the mains through them.

21. Ball hydrants form a ready means of ingress of polluting matter

into water mains and are therefore a potential source of danger. Water undertakers should take the first opportunity of having them replaced by safer types of hydrant.

Works of Repair and Cleaning

22. It is of the first importance that the arrangements made where works of repair or extension are being carried out are such as to obviate any risk of danger to the health of the consumer from contamination of the water supply. Instructions to workmen as to their conduct while engaged on such works should be in precise terms, and it should be made clear to them that any breach of the instructions will be followed by dismissal.

23. Where pumps or other machinery have been removed from a well or borehole for cleaning or repair, they should be thoroughly cleansed with chlorinated water before being replaced. New pumps or other machinery should be similarly treated before being inserted in the well or borehole.

Wells and Headings.

24. Where work is proceeding in a well or heading, the water therefrom should, whenever possible, be cut out of supply and pumped to waste. If this is not possible, the water should be subjected to an effective method of treatment during the period while the work is proceeding and for a period of at least one week after the work has been completed.

25. The workmen should be provided with boots and overalls which should be kept at the waterworks, and the boots should be cleansed with chlorinated water on every occasion before the men enter the well.

26. Sanitary arrangements should be provided at the surface and so designed that any risk of the men's boots being fouled is avoided. Pails, of a type which minimises the risk of splashing or overturning, should be provided for micturition where the men are working. Strict instructions should be given that any man wishing to defaecate must be brought to the surface and that micturition should take place in the pail provided.

Service Reservoirs and Filters.

27. Precautions similar to those referred to in the preceding paragraph should be taken as regards the provision of sanitary

arrangements for men engaged in cleaning reservoirs or filters. The pails for micturition purposes should be placed as near as conveniently possible to the place where the men are actually working. In the case of service reservoirs the precautions set out in paragraph 25 should be observed.

28. Service reservoirs when cleaned should be thoroughly sluiced with clean water, the water being chlorinated wherever practicable.

Maps

29. Each water undertaker should keep an up-to-date record in the form of maps and plans of the sites of their sources of supply and reservoirs and of their distribution system, so that they can ascertain readily how each property in their area is served. A diagram of the pipes and valves in and around engine houses and reservoirs should also be kept.

Errata

1. On page 806 of the May, 1939 Journal, in the 22nd line from the top of the page, the word "cystine" should be "cysteine."

2. On page 844 of the May, 1939 Journal, what is now given as "*The Jas. T. Fanning Formula*" should be: "*The J. T. Fanning Formula.*"

Bacteriological Examination of Water Supplies

A Book Review

By M. H. McCrady

THIS revision of Report No. 71, the first edition of which appeared in 1934 (and excerpts from which were published in the Eighth Edition of *Standard Methods of Water Analysis*) is of particular interest to American and Canadian water bacteriologists. Prepared by a Committee which includes a number of eminent British bacteriologists, it constitutes the practical British equivalent of Part VII of the American *Standard Methods of Water Analysis* employed on this side of the Atlantic.

The revision is very thorough. The arrangement of the material is very different from that of the former edition and much additional matter for the benefit of those readers, who may not be specialists in water bacteriology, has been included. The first edition consisted of only 38 pages, whereas the revision contains 59 pages.

The Prefatory Note summarizes the principal features of the revision as follows:

"There is no change in the purposes of this new edition as compared with the old, but the modifications introduced in its arrangement are intended to make it still more suitable for study by persons without special bacteriological knowledge, especially those who are concerned with the administration of water undertakings. . . . Thus, general information on the taking of samples, the rationale of the bacteriological analysis of water, the frequency and type of examination to be carried out, and the interpretation of the results has been

This is a review by M. H. McCrady, Chief of Laboratories of the Province of Quebec Ministry of Health, Montreal, of the revised edition of Report No. 71, *The Bacteriological Examination of Water Supplies*, published by the Ministry of Health, London, 1939. The text may be obtained from H. M. Stationery Office, London, or through any American importer of foreign publications. The price in London is 1 s. 3 d. net.

collected into Part I, while the technical description of the various methods of examination, which concern the bacteriologist alone, has been concentrated into Part II. Further, in order to facilitate the interpretation of the results for those not possessed of special bacteriological knowledge, a division of piped water supplies into four classes has been suggested. In this way it is hoped to avoid some of the misunderstanding that follows the expression in quantitative terms of the results of such a test as that for coliform bacilli, which is accompanied by a considerable sampling error independent of the skill of the technician. Special attention may be drawn to the desirability, stressed in the present edition, of carrying out simple routine tests at frequent intervals rather than of relying on more elaborate tests at longer intervals."

The objects with which the Report was prepared are stated to be:

"(1) To provide a description of technique the adoption of which will ensure sufficient uniformity in the practice of bacteriological examination of water to permit of comparison of the results obtained in different laboratories.

(2) To explain to Sanitary Inspectors and others the precautions necessary in obtaining and transmitting samples to the laboratory.

(3) To assist in assessing the results of bacteriological examination in terms of hygienic quality."

Part I of the Report begins with a note on the importance of judging the quality of a supply "on the sum of knowledge obtained by topographical and laboratory examination," and by investigation "of the conditions at the sources of supply and throughout the distribution system"; the necessity of establishing, wherever possible, a normal bacteriological standard for each particular water by means of frequent examinations is emphasized; and the advisability of increasing the frequency of examination when conditions, such as prolonged drought followed by heavy rains, etc., dictate such a course, is pointed out.

Sections on the care required in taking samples and on the rationale of the bacteriological analysis of water follow. In the latter section occurs a statement of the present trend in British practice that is especially interesting:

"It will be seen that the tendency of water analysis has been to pass from the more crude and less discriminative methods of chemical examination to the more delicate and more specific methods of bacteriological examination. At the present time, the trend of

practice among bacteriologists in this country is to concentrate on the demonstration of *faecal coli* in the water. Recently methods have been developed which enable a rapid enumeration of this organism, as apart from other organisms of the coliform group, to be made and it is anticipated that the quantitative estimation of *faecal coli* is likely in the future to play a dominant part in the routine control of water supplies. This does not mean to say that other types of coliform organism can be neglected, because there is evidence to show that some of these types survive longer in water than the *faecal coli* type, and hence may reveal by their presence more distant excretal contamination which, though not dangerous at the time of sampling, may nevertheless indicate that the water is subject to potentially dangerous pollution."

Section IV on the "Frequency and Type of Examination" discusses the frequency with which different kinds of supplies should be examined and the type of examinations that should be employed. Three procedures are described: (1) Simple Examination, consisting of a "*presumptive coliform count*," (with differentiation of coliform organisms into fecal and non-fecal types if necessary) using MacConkey broth. With fairly pure waters it is suggested that the test be made on one 50 c.c. and five 10 c.c. portions of sample; with other waters, usually on one 50 c.c., five 10 c.c. and five 1 c.c. portions. (2) Partial Examination, comprising both the *presumptive coliform count* (with or without differentiation) and nutrient agar *plate counts* at 22°C. (3 days) and 37°C. (2 days). "This type of examination should not usually be required for routine control purposes." It is intended for use when, because of suspected coliform results or unfavorable climatic conditions or other reason, additional information is desired. (3) Full Examination, comprising the *presumptive coliform count* (with or without differentiation), nutrient agar *plate counts* at 22°C. and 37°C., and tests for *fecal streptococci* and for *clostridium welchii*. This type of examination "should seldom be necessary except when a new supply is being considered, or the results yielded by the coliform test are ambiguous or suspected of being misleading."

There follows a brief discussion of the value of the *fecal streptococci* test, concluding that, although opinions on this point differ, the interpretation of the results of this test must, pending further investigation, remain doubtful,—and a similar discussion of the utility of the *Cl. welchii* test, pointing out that the presence of this organism, in the absence of coliform bacilli, indicates contamination of not very

recent date. "The chief value of the test would seem to lie in the detection of remote or intermittent pollution, especially in shallow well waters" where, although coliform organisms may have died out since the last access of pollution, *Cl. welchii* may still remain to serve as a warning of possible future pollution.

Section V, "Interpretation of Results," deals with the significance of the various bacteriological results under divers circumstances of climatic conditions, environment, etc. The *plate counts* and their ratio are first considered, then the *coliform count*, the probable sources of the different types of coliform organisms and the relative value of these types as pollution indicators. The following paragraph summarizes the significance to be attached to the presence of the coliform groups:

"In general terms, the presence of faecal coli denotes recent and possibly dangerous excretal contamination, which must be urgently attended to. The presence of I.A.C. (organisms of the intermediate, aerogenes or cloacae groups) in an untreated water suggests less recent contamination, which though not immediately dangerous is nevertheless sufficient to call for further steps towards obtaining greater purity of the supply. The presence of I.A.C. in a treated water suggests either inadequate treatment or the access of undesirable material to the water after treatment."

Section VI, "Suggested Classification of Waters," proposes that "piped supplies intended for distribution to populations of more than minimal size" be classified, with reference to the quality of the water *entering the distribution system*, as follows:

Piped Supplies

	Presumptive coliform count per 100 ml.
Class 1. Highly satisfactory	less than 1.
Class 2. Satisfactory	1–2.
Class 3. Suspicious	3–10.
Class 4. Unsatisfactory	greater than 10.

"Throughout the year 50 per cent of samples should fall into Class 1; 80 per cent should not fall below Class 2; and the remainder should not fall below Class 3.

"In chlorinated piped supplies the water, as mentioned below, ought to come into Class I."

It will be noticed that a probable number of 2 coliform organisms per 100 c.c. is permitted in *non-chlorinated* piped supplies.

The following two paragraphs, commenting on this classification,

are particularly indicative of the interpretation of coliform results that is recommended:

"If, in a *non-chlorinated* piped water supply, a fall occurs to Class 3, an immediate examination should be made to find out whether the coliform organisms are mainly of the faecal or non-faecal (I.A.C. and irregular) types. If they are found to be of the faecal coli type, then steps should be taken to insist on greater purity of supply. If they are of the non-faecal type, further steps towards greater purity of supply need not be taken at once, but analyses of the water should be made more frequently in case the appearance of non-faecal types heralds the advent of more serious pollution. With deep well, or other very pure waters, which normally fall into Class 1, a drop even to Class 2 should not be neglected, and an attempt should be made to detect any possible source of pollution.

"If a *chlorinated* water known to have been originally polluted, shows the presence of presumptive coliform organisms, an investigation into the efficiency and working of the treatment plant should be undertaken. *Efficient Chlorination Should Yield a Water Free from Coliform Organisms in 100 Ml.; That Is, Such a Water Should Fall into Class 1 of Our Grading.* Even making allowance for sampling and other errors, the appearance of these organisms in quantities of 100 ml., i.e. a fall to Class 2, should at once occasion misgivings as to the adequacy of the chlorination process."

In a brief discussion of the difficulty of securing adequate bacteriological control of small rural supplies the very pertinent statement is made that, "In rural areas, where frequent bacteriological examinations are impracticable, reliance must be placed almost exclusively on topographical examination."

Part II, called the technical part of the Report, contains a very detailed description of the method of performing the various tests, together with many useful and instructive comments on their relative utility.

The definition of *coliform* organisms, is practically identical with that of *Standard Methods* except that they must also be capable "of growing aerobically on agar media containing 0.5 per cent bile salt," for MacConkey Bile Salt Agar has long been the most popular medium in Britain for "plating out" cultures from fermentation-tubes.

The utility of MacConkey broth is discussed in some detail, the following excerpts indicating the regard with which this medium is

held in Britain: "We may point out that in this country MacConkey's lactose bile salt neutral red broth is widely used and has proved by experience to be admirably suited for this particular purpose. . . . It is true that the bile salt has a slight inhibitory effect on the growth of the coliform organisms themselves, but this disadvantage is more than outweighed by the practically complete elimination of false positive reactions. With very few exceptions it may be taken that the production of acid and gas in MacConkey medium inoculated with water indicates the presence of coliform bacilli. . . . The presumption (of presence of coliform organisms) is, *in this country*, however, very high. In other countries, where the water flora is different, false positive reactions in this medium may not infrequently be encountered (Atkinson and Wood,[1] 1938)."

Considerable space is devoted to the sampling error of the coliform count. After emphasizing the necessity of employing the Most Probable Number method of interpreting fermentation-tube results, the error to which this estimate is subject is discussed in some detail. Since this point is of particular importance the argument is quoted in full:

"How then are we to report the results of the coliform test? Fortunately what we really want to learn from the test is not the exact numbers of coliform bacilli present, but the maximum numbers that may be present. Supposing, for example, we allow 3 or 4 coliform bacilli in every 100 ml. of a piped water supply, and 15 in every 100 ml. of a non-piped supply, we want to know how often the probable number of coliform bacilli obtained from the tables is likely to underestimate the real number. While it is true that the variations given above may occur occasionally, it must be remembered that these are extreme variations. In actual practice the great majority, somewhere about 80 per cent, of the probable figures given will fall between about one-half and double the real figure. If, for example, the real number of coliform bacilli per 100 ml. is 2, then a probable figure of between 1 and 4 bacilli per 100 ml. will usually be obtained. If the probable figure exceeds the real figure, the water may be unjustly condemned; but if the probable figure is less than the real figure, there is a danger that a contaminated water may be passed as satisfactory. It is this latter contingency which we must guard against.

[1] Atkinson, N., and Wood, E. J. F. Aust. J. Exp. Biol. Med. Sci., 16, 103, 111 (1938).

"From Halvorson and Ziegler's work[2] it would appear that the chance of obtaining a probable figure less than half the real figure is approximately 15 to 1 against. Consequently if we base our standard on the probability figures, we must be careful to select such a figure as will more or less guarantee that the real number of coliform bacilli present is not likely to exceed a dangerous limit. If, for example, the probable figure given by the tables is 1 per 100 ml., then it is unlikely that the real figure will be greater than 2 per 100 ml. It is for this reason that the standards we have laid down in Section VI may seem to be unnecessarily severe. In the interpretation of these standards, however, it must be remembered that the probable figure is as likely to over-estimate as to under-estimate the real figure. In practice, therefore, the occurrence of a probable figure exceeding the standard laid down is bound to occur fairly frequently even when the real number is within the standard. For practical purposes, provided the standard is not exceeded more than once in 5 or 10 examinations, no undue alarm need be experienced."

Differentiation of coliforms into the *Esch. coli*, the intermediate and the aerogenes-cloacae groups is effected by means of the usual methyl red, Voges-Proskauer and citrate-utilization tests; for subdivision of these groups, the indol test, the gelatin-liquefaction test and the 44°C. MacConkey test (a test for production of acid and gas in MacConkey broth incubated in a water bath at 44°C. for 48 hr.).

Table 1 on the following page shows the differentiation proposed.

It is pointed out that, since the ability to form indol is characteristic of certain intermediate and aerogenes strains, "a positive reaction has not therefore the differential significance which has often been attributed to it in the past. It is of value, however, in distinguishing between the faecal and non-faecal types of Bact. coli."[3] Gelatin liquefaction is said to be of little importance, serving merely to differentiate between *Aer. aerogenes* and *B. cloacae*. As regards the utility of the 44°C. MacConkey broth test, it is concluded that "The test still awaits trial on an extensive scale, but the data so far accumulated seem to justify its application to routine work. Practically every strain forming gas in MacConkey at 44°C. appears to

[2] Halvorson, H. O., and Ziegler, N. R. *Quantitative Bacteriology*, 64 pp., Burgess Publishing Co., Minneapolis.

[3] EDITOR'S NOTE: The terms *Bact. coli*, *Bact. aerogenes*, and *Bact. cloacae* are used in this review in place of the American terms *Esch. coli*, *Aer. aerogenes*, and *B. cloacae* where the former terms are directly quoted from the British publication. Where the language of the reviewer appears, the terminology conforms with American practice.

belong to the faecal coli type, but whether every strain of faecal coli will form gas at 44°C. is still in doubt."

The possibility of detecting the presence of fecal coli by direct transfer from a MacConkey presumptive to a MacConkey tube at 44°C., is indicated as follows:

"On the other hand, in a modified form the method can be applied very satisfactorily to water analysis. What the bacteriologist mainly

TABLE 1

Differentiation of the coliform group

	M.R.	V.P.	GROWTH IN CITRATE	INDOLE	GAS IN MACCONKEY AT 44°C.	GELATIN LIQUEFACTION 7 DAYS	PROBABLE HABITAT
Bact. (Esch.) coli, type I, faecal	+	−	−	+	+	−	Human and animal intestine
Bact. (Esch.) coli, type II	+	−	−	−	−	−	Doubtful; probably not primarily intestinal
Intermediate, type I	+	−	+	−	−	−	Mainly soil
Intermediate, type II	+	−	+	+	−	−	Mainly soil
Bact. (Aer.) aerogenes, type I	−	+	+	−	−	−	Mainly vegetation
Bact. (Aer.) aerogenes, type II	−	+	+	+	−	−	Mainly vegetation
Bact. (B.) cloacae	−	+	+	−	−	+	Mainly vegetation
Irregular, type I	+	−	−	+	−	−	Human and animal intestine
Irregular, type II	+	−	−	−	+	−	Doubtful
Irregular, other types	Reactions variable						Doubtful

wants to know is whether organisms of the faecal coli type are present in more than minimal numbers. If they are, then the additional presence of I.A.C. organisms is of no practical interest. It is only when faecal coli are absent that the presence of other types of coliform bacilli becomes important. In practice, therefore, all fermented 37°C. MacConkey tubes can be subcultured into MacConkey broth at 44°C. If faecal coli are present, nothing more need as a rule be done, but if they are absent then the original fermented 37°C. MacConkey tubes can be examined by methods described on p. 35 for the presence of I.A.C. organisms."

One is tempted to question whether, in the use of this procedure, the long delay intervening between the formation of gas in the original MacConkey presumptive and the final search for I.A.C. organisms might not result in loss of some of the latter through overgrowth by other organisms or because of the production of excess acid in the tube.

The utility of incubating the original MacConkey tubes at 44°C., for immediate detection of the presence of fecal coli, is discussed, but the information available is said to be "deficient and to some extent conflicting." Further investigation of the possibilities of this procedure is recommended.

Two techniques for demonstrating the presence of *faecal streptococci* are offered, one dependent upon the fact that they are more resistant to heat than most coliform bacilli, whereas the other takes advantage of their resistance to certain concentrations of potassium tellurite. The latter method is considered to be the better. The streptococci form small bluish-black colonies, with a peripheral opalescence, on lactose agar (peptone 1.0, lactose 0.5, dipotassium hydrogen phosphate, anhydrous, 0.2, sodium chloride 0.5, agar 2.0, water 100) containing 1 to 15,000 potassium tellurite. (The latter is dissolved in water at a temperature below 40°C., and added after the medium has been sterilized; otherwise reduction of tellurite may occur.) Suspected colonies are fished and submitted to morphological, cultural and biochemical examinations.

For demonstrating the presence of *Cl. welchii*, two methods are proposed:

(a) direct planting of sample portions into litmus milk tubes, heating the mixtures at 80°C. for 10–15 min., and incubating anaerobically at 37°C. for 72 hr.

(b) direct planting of sample portions (20–40 c.c.) in a special sulfite glucose agar (Wilson and Blair),[4] and incubating 24–36 hr. at 37°C. Large black colonies (3–5 mm. in diameter) are formed by *Cl. welchii;* some coliform organisms also, however, produce similar colonies.

Appendices A, B, C and D of the Report contain respectively instructions for collecting samples, directions for preparing glassware and other apparatus, methods of preparing media, and McCrady's tables of Most Probable Numbers.

[4] Reference is on page 174 of the Seventh Edition of *Standard Methods of Water Analysis:* Wilson, W. J., and Blair, M. M. Correlation of the Sulfite Reduction Test with Other Tests in the Bacteriological Examination of Water. J. Hyg., 24: 111 (1925).

Comment

Because of the fact that an inhibitive ingredient, bile salt, is employed in MacConkey broth, the use of this medium may be expected to yield, upon the whole, fewer coliform isolations than that of a simple medium such as standard lactose broth. The results secured from rather polluted waters, however, are probably much the same whichever medium is employed. Available data for comparison of the two media, when used for examination of the better classes of waters, are so few that their relative value for such work is still in doubt, but it is probable that the multiplication of some of the coliforms in such waters is inhibited by the bile salt of MacConkey broth.

The use of the MacConkey presumptive (acid and gas) without confirmation, as frequently practised in Britain, has been shown to yield, in certain other lands, a disturbing proportion of false presumptives. Available information indicates that the frequent occurrence of false presumptives likewise militates against its general use in America. The relatively large proportion of *Esch. coli* in the British coliform flora apparently accounts for the differences in the experiences recorded.

It is very unfortunate that no standardization of the bile salt employed in MacConkey broth has been effected. The uncertainty regarding the effect of different brands of this important ingredient leads one to question whether uniform results from the use of this medium are always assured.

The Report is replete with valuable suggestions regarding that most difficult subject in water bacteriology, the interpretation of results; and the very complete detailed directions for performing every operation, from collection of samples and preparation of apparatus and media to the final reporting of results must make it a most welcome handbook to British laboratory workers who have not specialized in this field of bacteriology.

American and Canadian water bacteriologists will find the Report very stimulating and helpful. Although the bacterial flora in British waters is apparently somewhat different from that found in waters of this continent, particularly as regards the relative frequency with which *Esch. coli* and *Aer. aerogenes* are encountered, and although this fact must therefore be constantly kept in mind when perusing this Report, it contains so many suggestions and arguments applicable to the practice of water bacteriology in general that every worker in this field should be thoroughly familiar with it.

ABSTRACTS OF WATER WORKS LITERATURE

Key. **30:** 402 (Mar. '38) indicates volume 30, page 402, issue dated March 1938. If the publication is paged by issues, **30:** 3: 402 (Mar. '38) indicates volume 30, number 3, page 402. Material inclosed in starred brackets, ★[ ]★, is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British).*

CEMENT AND CONCRETE

Portland Cement. THADDEUS MERRIMAN. Boston Soc. Civ. Eng. **26:** 1 (Jan. '39). Behavior of concrete made with portland cement is a perplexing problem to engineers; most concrete is sound, durable and satisfactory, but a disturbingly large amount disintegrates at an early age. Major and probable cause often is to be found in cement rather than the other reasons for failure which are usually given. Quality of a cement as related to quality of concrete it is capable of producing depends upon (1) its composition, (2) methods and care employed in mfgr. and (3) care with which handled after mfgr. The more thorough and more uniform is the blending, mixing and burning of the cement constituents the better will be the resulting product. Principal compounds in clinker are those between silica and lime, which in the pure states combine only under high temps., and carefully controlled conditions. Oxides of Al and Fe make these compounds form more readily, but they must not be in too high conc. to make cement "easy" to burn. To get proper burning, temp. must be varied to meet various combinations of constituents. In general, author states, it may be said the quality of the product of the av. rotary kiln varies between wide limits and from "good" to "bad" with intermediate predominating. For all practical purposes, quality of a portland cement may be considered by picturing it as a mixture of several compounds, each with its own characteristics and qualities. Board of Water Supply of N. Y. City specifications discussed. These are result of study and research over past 25 yrs. Prin. features are: Al_2O_3 content shall not exceed 5.60%; SiO_2 content shall not be less than 21.50%; MgO content not to exceed 4.0%; SO_3 not to exceed 1.75%; loss on ignition not to exceed 0.90%; ratio alumina to iron shall lie between 1.2 and 1.6; ratio lime to silica shall not exceed 2.90; shall pass sodium sulfate test; shall pass sugar solubility test; etc. Spec. also given to secure uniformity of clinker. Sugar solubility and sodium sulfate test methods given and discussed. Spec. of Board given in appendix to article.—*Martin E. Flentje.*

Giant Dams of America and Special Cements Therefor. Bo Hellström. Teknisk Tidskrift (Stockholm) **69:** 213 (Apr. '39). Recent decades have witnessed impressive developments in cement manufacture. Annual output in Sweden has grown from 442,000 barrels in 1898 to 5,805,000 barrels in '38; while av. 28-day compressive strength has increased from 400 kg./cm². in '08 to 585 kg./cm². in '38. As cement improved, so have monoliths increased in size, creating a heat problem of great difficulty. Owing to low conductivity, temperature reached in setting in the interior of a 20-meter thickness of concrete may exceed 50° or even 60°C. and so slow is the natural cooling process that at the end of five years more than 20% of this additional heat will still be retained. As the mass slowly cools and contracts, stresses of great intensity develop and wherever the tensional strength of the concrete is exceeded, cracks must occur. Always undesirable, these are particularly objectionable in water-retaining structures, impairing alike stability, tightness, and durability. Many methods to combat cracking have found acceptance, such as frequent expansion joints, great care of exposed surfaces, and methods aimed at reducing the amount of cement needed per cubic meter of concrete. More helpful than these have been cooling by means of circulating water and the development of special cements. Low-heat cement was given its first large-scale trial in '32 in the Morris Dam: in '34 the Bureau of Reclamation issued its first specification for low-heat cement for Boulder Dam. International interest in special cements was aroused at the '33 congress in Stockholm, and the Washington congress in '36 was notable for Dr. Savage's memorable address on this subject. Moderate-heat cements, a later type, were used in the Norris Dam, the Tygart Dam, and the lower part of the Grand Coulee Dam. Later still, portland-pozzolan cements have been used in the piling for the great San Francisco bridges, because of their resistance to attack by sea water. The present ('39) trend is back to low-heat cement which has now proved itself to be exceptionally free from cracking. Some of the chief features of the following dams are summarized and illustrated:—Boulder Dam, Parker Dam, Marshall Ford Dam, Seminoe Dam, Bartlett Dam, Grand Coulee Dam, Hiwassee Dam, Shasta Dam, and Friant Dam. As regards the vexing problem of crack formation, the perfect candor of American engineers is beyond all praise. Complete freedom from cracking, even with low-heat cement and water-cooling in combination, has yet to be attained; but it is now well established that, with low-heat cement, cracks are fewer and smaller than with ordinary cement. Factory price on low-heat cement for Boulder Dam was 4% more, and on that for Morris Dam, 5.5% more, than that of ordinary cement. Corresponding increase in cost of concrete was less than 1%. Portland-pozzolan cement is attracting great interest, but is regarded as being still more or less in the tentative stage. Already in '31, power companies in Sweden were calling for special cement for dams, and thanks to överingenjör Axel Ekwalls and doktoringenjör Lennart Forsens, Swedish accomplishments in this field now surpass those of most other European countries. Silikatcement was on the market in '32, and Pansar cements, of portland-pozzolan type, in '34. These cements develop 20% to 30% less heat than ordinary cement; their initial strength is less than that of ordinary cement, but at the end of a year, their strength exceeds that of ordinary cement.

Present conditions in Sweden offer an exceptionally favorable opportunity for comparative study of the behavior of the different types of cement and the Swedish committee on high dams is planning to make the most of them.—*Frank Hannan.*

The Field for Low-Heat Cement. H. S. Meissner and W. T. Moran. Eng. News-Rec. **121**: 589 (Nov. 10, '38). Researches which led to development of low-heat cement and experience gained in its employment and production are reviewed. Principle involved is reduction of tricalcium aluminate and tricalcium silicate contents, together with finer grinding to restore strength lost at early ages through low tricalcium silicate content. About ⅓ less heat is generated on hydration than with standard portland cement and the heat is produced much more slowly and over longer period of time. Low early-strength in winter must be allowed for and a more prolonged curing period is desirable. Strength at later ages equals or exceeds that of concrete made with standard cement. Experience on large dams has shown that use of low-heat cement results in less cracking than is usual with standard cement and, due principally to greater fineness, increased workability, greater freedom from bleeding and reduced water requirements. Low-heat cement clinker shows greater resistance to grinding. "Modified" cements, evolved from research and experience with low-heat cement, which differ from latter in that tricalcium silicate content or $CaO:SiO_2$ ratio is higher, have some of more desirable characteristics of low-heat cement while retaining initial strengths equal to standard cements. Temp. cracks are less than with standard cement but are not reduced to as great an extent as with low-heat cement. Tabulation of physical and chemical properties of various type portland cements is included.—*R. E. Thompson.*

The Reactions between Silica and Calcium Oxide in Aqueous Solutions and their Relation to Pozzolanic Action, Alfred E. Beitlich. J. Am. Chem. Soc. **60**: 1832 (Aug. '38). As shown by conductivity measurements in dil. solns., SiO_2 adsorbs CaO in accordance with the Freundlich adsorption isotherm. Above $CaO:SiO_2$ ratios of 0.30 and up to 0.6, chemical combination occurs, product being $CaO \cdot 2SiO_2$, stable in soln. contg. 1.5 mg. eq. of CaO per liter. With $CaO:SiO_2$ ratios above 0.6, adsorption again occurs up to $CaO:SiO_2$ value of 0.9, and product is $4CaO \cdot 5SiO_2$, stable up to 10 mg. eq. of CaO per liter. With higher CaO concns. and initial $CaO:SiO_2$ ratios of 1.3 to 3.75, adsorption again occurs. As point of saturation of CaO soln. at equilibrium is reached, ratio of CaO to SiO_2 in reaction product approaches 2, indicating probable existence of a hydrated $2CaO \cdot SiO_2$ in satd. CaO soln.—*Selma Gottlieb.*

The Use of Concrete in Water Works Structures. Anon. Eng. Cont. Rec. **52**: 15: 39 (Apr. 12, '39). Architectural concrete has brought to design and construction of waterworks plants new beauty combined with functional usefulness. Each yr., more architectural concrete waterworks are being built. In their design may be incorporated architectural embellishment that best suits surroundings or buildings may be given simple and severe lines if accentuation of functional purpose is desired. General rules applicable to

architectural concrete construction include: accurate control of aggregate sizes, careful design of forms, selection of and use of only light film of form oil (inexpensive lacquer is now available which gives excellent results, leaving concrete unstained and light in color), location of construction joints at inconspicuous points, thorough compaction (vibration is desirable) to ensure even surface free of stone pockets, and strict adherence to specifications governing selection and mixing of materials. Architectural treatment of waterworks plant at Fort Knox, Ky., is described briefly and use of concrete in no. of plants in U. S. is illustrated.—*R. E. Thompson.*

Design of Circular Concrete Tanks. GEORGE S. SALTER. Proc. A.S.C.E. **65**: 419 (Mar. '39). The paper provides a simple and direct method of designing circular, concrete tanks. It is shown that by fixing the wall at the base so that the liquid pressure is divided between circular rings and the vertical cantilevers, the magnitude of the maximum ring tension is greatly reduced. For tanks of proportions such as are ordinarily used for settling purposes the maximum ring tension amounts to only about one-fourth to one-third, and the total amount of wall reinforcement to less than one-half, of that required were the wall free at the base. Diagrams are presented to facilitate design and a numerical example is given showing their application. Although the analysis applies to tanks of all sizes, the diagrams presented apply only to tanks of proportions such as are ordinarily used for settling purposes.—*H. E. Babbitt.*

Expansion Joints in Water-Retaining Structures. G. SCHACKNE. Teknisk Tidskrift, Uppl. E (Stockholm) **68**: 129 (Nov. '39). Experiences with joints in a concrete dry-dock. Joints should be designed for 50% over the extreme movement predictable. Describes and illustrates several types of joints using asphalt and asphalted felt and with the reinforcement bars, where they cross the joints, coiled into spirals or else prevented from bonding on one side by oil or asphalt application. Metal test plugs set in the concrete each side of joint indicated movement ranging from 1 to 5 mm. across joints 100′ apart in heavy quay walls. Another procedure was to pour walls in about 80′ sections with 6′ gaps poured 30–45 days later after volume changes due to setting completed. Cost of joints saved many times over by reduction in later maintenance. *Discussion.* NILS BERG: Considers more joints, of simpler type, preferable and cites case of joints consisting merely of a stainless steel plate extending into the concrete 8″ on each side of the joint, which were perfectly water tight under 60′ head. More complication necessary, however, where displacement in every direction is to be provided for. Describes and illustrates joint with asphalt retained in a wide groove by steel plates bolted on one side and sliding in a slot on the other side of the joint; asphalt kept under pressure to make up losses by continuous automatic feed from over head. Another case described and illustrated of sheet steel piling driven through a dam to form a longitudinal cut-off and bedded at bottom in an asphalt filled trough previously prepared for it in the concrete sub-structure. HERMANN JANSSON: Best spacing of joints dependent on thickness of walls as well as

other factors. Many cracks originate from too rapid drying of concrete. Design of joints must take account of difficulties of practical construction.—*Frank Hannan.*

Cleaning Concrete Surfaces to Ensure Bond. DANIEL MCFARLAND. Eng. News-Rec. **120:** 682 (May 12, '38). Methods used at Grand Coulee Dam are outlined briefly. All concrete is required to set 72 hrs. before new concrete is added, sprinkling being carried on nearly constantly during curing period. Water-air jets and power-driven brush with steel wire bristles and equipped with water jet to remove cuttings have been experimented with.—*R. E. Thompson.*

Vibration is Revamping Concrete Mixing and Placing Methods. A. E. LINDAU. Eng. Cont. Rec. **51:** 24: 17 (Jun. 15, '38). Vibration permits use of harsh dry mixes which are desirable for economy and durability, increases workability, eliminates honeycombing, improves bond between successive layers of concrete and between concrete and reinforcing and renders concrete more impervious to water. Forms properly built for hand-placing are adequate for vibration. Internal vibrators have largely replaced other types for field work owing to their convenience and greater effectiveness. Speed or frequency of vibration is most important factor in obtaining satisfactory results. Simple rules concerning employment of vibration are outlined.—*R. E. Thompson.*

Long Continued Vibration Reduces Concrete Strength. W. B. IVIE. Eng. News-Rec. **121:** 255 (Sept. 1, '38). Two shafts of concrete, 6″ in diam. and 6′ long, were cast in forms made by placing standard bottomless cylinder molds on top of one another, taping the joints and bracing the molds with lumber. Concrete placed in 1′ lifts, each lift being vibrated internally for 45 sec. in one case and for 5 min. in the other. Strength tests after 28 days' indicated that the longer continued vibration had tendency to cause segregation, with consequent weakening of upper portion and strengthening of bottom portion. Examination of fractured specimens clearly showed evidence of water collecting on underneath side of coarse aggregate in top sections.—*R. E. Thompson.*

DAMS

Bigger Than Boulder. ANON. Eng. News-Rec. **120:** 647 (May 5, '38). Details are given regarding Shasta Dam on Upper Sacramento R. in Calif., key unit in great Central Valley irrigation and flood control project, on which bids will be opened June 1. Dam will be of gravity type, with straight center spillway 375′ long and slightly curved abutments, which will rise on 3:1 slope from streambed width of 150′ and at left end, where depth to sound rock is very great, will terminate in rolled earth-and-rock fill enclosing concrete core wall. At top, total length of dam is about 3,500′, of which gravity section accounts for 2,860′, and width is 37′. Concrete volume in gravity section will be 5,400,000 cu. yd. and extreme height 560′ from lowest foundation to top of roadway: gross storage capacity will be 4,500,000 acre-ft. To regulate flow

through dam during normal operation, thirteen 102″ diam. steel-lined conduits will be provided extending through spillway face. Discharge will be controlled by ring-seal gates. For close regulation of flow, two 86″ diam. conduits, controlled by 60″ needle valves in power house, will be used. Spillway terminates in apron 260′ long, warped near end to produce hydraulic jump to dissipate energy of water falling from unprecendented height of 487.5′. Low-heat cement will probably be used and system of cooling pipes will be incorporated in concrete mass. Artificial refrigeration will probably not be required. Construction period is estimated at 5 yrs.—*R. E. Thompson.*

Highest Multiple Arch Dam. ANON. Eng. News-Rec. **121**: 13 (Jul. 7, '38). Bartlett Dam, under construction by Bureau of Reclamation on Verde R., 54 mi. north of Phoenix, Ariz., will be highest multiple-arch concrete dam ever built. It will rise 287′ above its foundations to impound 201,500 acre-ft. of seasonal flood waters in 3,170-acre reservoir for release to lands of Salt R. Valley irrigation project, thus supplementing present supply which comes down Salt R. (of which Verde R. is tributary) through 4 reservoirs formed by Roosevelt, Horse Mesa, Mormon Flat and Stewart Mountain Dams. Careful investigation indicated multiple-arch dam to be most suitable and economical, and preliminary studies, model tests and structural analyses were all carried out with extra thoroughness. Authoritative records list only about 30 multiple arch dams in world that exceed 100′ in height, and only 3 rise above 200′. Dam is 750′ long, exclusive of 170′ spillway, and is made up of 10 arch barrel sections, intervening buttresses and short gravity sections at each abutment. Spillway will discharge 225,000 sec.-ft. at max. flood stage, at which time 25,000 sec.-ft. will also spill over dam. Site is unusually good, consisting of canyon only about 275′ wide at bottom, about ½ of which is occupied by river, and with fairly steep wall slopes which flatten out near top. Ideal foundation is provided by fine-grained granite covered with about 70′ of fill in river channel but exposed on abutments. Old fault, about 3′ wide at most, crosses canyon at site, but geologists agree that region is not now subject to earthquakes. Concrete, about ½ of which has been placed, is being transported largely by pumpline. Low-heat cement is being used and all concrete is vibrated. Forms (described) required are relatively intricate. Specifications for grouting cutoffs around upstream edges of arches and buttresses required holes alternately 75 and 100′ deep into foundation rock on 5′ centers. Special technique was developed to avoid displacing foundation rock or concrete that had been placed. Procedure was to grout all holes to 10′ and then stage grout 100′ holes between 10 and 40, 40 and 70 and finally 70 and 100′; 75′ holes were then grouted from 10 to 75′ at single stage. Pressure varied from 50 lbs. per sq. in. for first 10′ below surface to max. of 350 lbs. at 70–100′. If uplift, as indicated by precise levels on rock and concrete in vicinity, reached 0.004′ grouting pressure was reduced and if uplift then continued work was transferred to another hole.—*R. E. Thompson.*

Raising O'Shaughnessy Dam. ANON. Eng. News-Rec. **122**: 707 (May 25, '39). Details of raising of O'Shaughnessy Dam, storage structure for Hetch Hetchy water supply of San Francisco. Height increased 85.5′, and capacity

of reservoir 154,000 acre-ft. When original dam was built (completed '23), full section for additional height was brought up to streambed level and downstream face above was stepped to facilitate bonding when addition was made. Important objective in making addition was to give new concrete same strength and modulus of elasticity as old within construction period and to provide adequate distribution of stress. Important factors in accomplishing this were: (1) advances made in concrete technology, (2) artificial cooling of concrete with aid of refrigeration, which made possible (3) early effective grouting. Large part of additional concrete placed on downstream face was not poured directly against old structure. Slots with av. thickness of 5′ and length of 20′ were left open along joint between old and new concrete: only narrow ribs (2′ thick), sufficient to support wt. of new concrete, were allowed to make direct contact. Concreting of these slots was delayed until shrinkage had occurred in adjoining concrete. After artificial cooling of concrete in slots, surrounding joints were grouted. Final operation was grouting of contraction joints in old and new portions of dam. Old surface was roughened to improve bond and $1\frac{1}{4}$″ square steel bars were set in old downstream face to depth of 5′. Bars were cut in lengths of about 15′, thus projecting through slots and 5′ into new concrete. Spillway for enlarged structure is of open channel type with weir crest 195′ long in three 65′ sections. Cost was $3,477,000.—*R. E. Thompson.*

The Dunwan Reservoir. JAMES SEMPLE. Civ. Eng. (Br.) **24:** 9 (Jan. '39). The scheme for supplementing the water supply of the Eastwood and Mearns Water District of the County of Renfrew comprises construction of two reservoirs, a mechanical filter plant, and two concrete clear-water tanks. The work will add 2 m.g.d. (Imp.). New reservoir will have capac. of 300 mil. gal. (Imp.) with a catchment area of 1,180 acres. An earth dam, with max. water depth of 33′, will form the reservoir. The reinf. concrete bell-mouth spillway is of special interest. It has an overall diam. of 33′ and effective length of 86.5′. Shaft is 21′ diam. Tests were made on a 1:24 scale model before erection. Calculated max. depth over sill is 1′-8″ for a most exceptional flood. During construction work provisions were made to safeguard existing fishing rights and to allow for possible floods. All masonry surfaces exposed to water action are faced with a 2″ granolithic, consisting of 2 parts crushed stone to 1 part cement. Provision made in the intake tower for installation of copper-gauze screens. All compensation and waste water is discharged through the outlet tunnel and flows into a measuring well at the tail bay immediately below the embankment.—*H. E. Babbitt.*

The Subsidence of a Rockfill Dam and the Remedial Measures Employed at Eildon Reservoir, Australia. J. Inst. C. E. (Br.) No. 8: p. 451 (Oct. '38). *Discussion of paper by* RUPERT GRENVILLE KNIGHT. See abstract J. A. W. W. A. **30:** 1018, 1019 (June. '38). E. V. CLARK: Was surprised that the embankment, with its thin diaphram core wall, should have been built without consolidation of the fill. H. H. DARE: Observes that the design of the rock-fill section of Eildon Dam was generally similar to that of an earlier structure on the Werribee River at Melton which had been standing satisfactorily for 20

yrs. L. R. EAST: In comparing the prototype at Melton with the Eildon Dam sufficient differences are discernible to justify the freedom from trouble at the Melton Dam. A. E. KELSO: Believes that the total measured leakage through the restored structure was to be considered moderate in view of the severe damage to which the original structure had been subjected. In making repairs, however, the reinforcing steel had been left exposed in some of the major cracks, raising doubt as to the future behavior of the structure. A. D. LEWIS: Four major defects in the original design dealt with: (1) placing of the rock-fill on soft material, (2) cut-off wall should have been on upstream face and not at the center, (3) having placed the wall in the center the steep clay bank against the upstream face should have been omitted, and (4) it is possible that a large proportion of the rock-fill material was liable to rapid deterioration. DAVID LLOYD: Makes a theoretical estimate of the runoff from the watershed as 25.7″. Observed runoff was 26.6″. He questions the closeness of the estimate as fortuitous and requests further information concerning factors which might affect this agreement. JAMES MITCHELL: Observes that the support of a wall 90′ high and built of clay which had been selected for its plasticity would be a difficult problem under any circumstances. W. H. R. NIMMO: Points out that the failure by slumping of several hydraulic-fill dams had clearly demonstrated the disastrous results which might follow from the inclusion of a great thickness of extremely fine clayey material in the center of an earthen dam. E. G. RITCHIE: States that not the least danger taught by this failure was that of reducing profiles in a dam composed of loose rock fill. Fundamental error in the design was assumption that the loose rock fill would weigh 90 lb. per cu. ft., a figure probably too high. E. D. SHAW: Points out that the dam had been used for two years since its reconstruction, vindicating the methods used for repairs and adding greatly to the information available. C. P. FARIE WRIGHT: Noted some errors in author's paper in stating the weight of the rockfill to be 90 lb. per cu. ft., but the weighings by the Board of Inquiry found it to be 94 lb. for Pinniger material and 104 lb. for material from Mt. Sugarloaf. THE AUTHOR: (*closing discussion*) Observed that the rock-fill dam had far outstripped its pioneering predecessor and had entered the sphere of scientific design. ★[In the discussion, valuable information is included concerning materials put into the dam before and after failure, run-off data, design details, preliminary tests and investigations, and an appendix includes an exhaustive report of soil tests on clay samples from the reservoir.]★—*H. E. Babbitt.*

The Gorge Dam, Hong Kong. W. J. E. BINNIE AND H. J. F. GOURLEY. J. Inst. C. E. (Br.) No. 6: p. 179 (Apr. '39); *also* Engineering (Br.) **147**: 134 (Feb. 3, '39), Surveyor (Br.) **95**: 212 (Feb. 3, '39) *and* Civ. Eng. (Br.) **24**: 63 (Feb. '39). The Jubilee Reservoir for the water supply of Victoria, capital of the colony of Hong Kong, has a catchment area of 3,000 acres. It is formed by means of two dams,—one known as the Gorge Dam is across a narrow gorge through which the Shing Mun River flowed, the other is known as the Pineapple Pass Dam across a depression in a ridge. Uneven, although high, annual rainfall which amounts to 100″ will result in estimated yield of 9¼ m.g.d. (Imp.) which would be increased to 14 m.g.d. when the first catch-

water discharging into the reservoir at Pineapple Pass dam was constructed. Dam is approx. 275′ high above stream bed and has length of 690′ at top. It is a composite structure consisting of five portions: (1) the cut-off wall, (2) the articulated face concrete, or "diaphragm," (3) the main portion of the concrete construction or "thrust block", (4) the "rock-fill" which takes a portion of the water pressure, and (5) the "sand-wedge" which is interposed between the thrust block and the rock-fill. During construction the river was diverted through a 15′ tunnel. Spillway consists of a circular bellmouth which discharges into the river diversion tunnel. Model tests on the bellmouth show that there will be a steady discharge up to 10,500 c.f.s., above which there will be formation and destruction of a vacuum. The value of C in the expression $Q = LCH^{3/2}$, in which Q is the discharge in c.f.s., L is the length of the spillway in ft., H is the head of water on the spillway, in ft., and C, a coefficient, was found to be 3.14 up to a value of H of 7′. It was decided to incorporate six automatic siphons in the dam, each capable of discharging 500 c.f.s. (See also: *Model Experiments on Bellmouth and Siphon Bellmouth Spillways.* G. M. Binnie. J. Inst. C. E. (Br.) No. 1: p. 65 (Nov. '38), discussing experiments which led to the design used for the Gorge Dam.)—*H. E. Babbitt.*

Improving Foundation Rock for Dams. James B. Hays. Civ. Eng. **9**: 309 (May '39). In general there are two objectives in grouting a dam foundation: (1) elimination or reduction of leakage, and (2) consolidation of the rock in order to assure a uniform deformation that will approach the deformation assumed in design. Cement is the only material which has been found satisfactory in grouting under masonry dams. Sand is sometimes added to the grout under special circumstances. Grouting holes are usually located along the upper face of the dam and spaced 4′ to 20′ apart. Where there is danger that uplift may occur during grouting uplift indicators are used. In large, massive layers, holes 50′ deep can be given pressures of 100 lb. with safety. In thin-bedded, horizontal strata, 25 lb. may produce uplift in holes of the same depth. Pressures as high as 1,000 lb. have been used. In general, it is best to start each hole with a thin mix and to increase the consistency with each batch, until about 75% of the final pressure desired is reached. The pumping rate should be uniformly constant. Chemical grouting is useful in the solidification of sand and gravel, the most common chemical used being sodium silicate, either alone or sometimes combined with cement grout. Recently a process has been developed that provides for mixing the chemicals in such a way as to control the time of set.—*H. E. Babbitt.*

Stresses Around Galleries in Concrete Dams. Ivan E. Houk. The Engr. (Br.) **166**: 382 (Oct. 7, '38). Stresses around galleries in concrete dams must be evaluated if reinforcement is to be provided to prevent undesirable cracks which may otherwise develop along the gallery walls. Experimental measurements on laboratory models showed that actual stresses around circular openings agree closely with those computed by theoretical equations, where distances from gallery to face of dam were more than 7 times gallery diameter. Formulas for various principal stresses are given. Models of various types

of dams were constructed and loads applied by air compressed in bags confined against portions of the model. Satisfactory correlation found between theoretical and measured stresses.—*H. E. Babbitt.*

52-in. Rotary Hydraulic Valve for Waikaremoana, New Zealand. ANON. Engineering (Br.) **147**: 370 (Mar. 31, '39). The control of great volumes of water at high velocity and pressure is successfully met by the spherical rotary, full-bore valve. The 52″ Boving-Darling valve is designed for a working head of 630′. This, and two smaller valves described in the article, are externally spherical, the waterway being formed by a cylindrical passage straight-through, bored to a fine finish. The valve proper is pivoted on a pair of trunions, one of which carries a crank coupled by a connecting rod to the piston of a hydraulic servomotor. The opening and closing motion is purely rotatory, and effectively prevents "slam."—*H. E. Babbitt.*

The Protection of Dams, Weirs, and Sluices against Scour. ROBERT VALENTINE BURNS AND CEDRIC MASEY WHITE. J. Inst. C. E. (Br.) No. 1: p. 23 (Nov. '38). Report of extensive studies made by use of small-scale models. In deciding on the scale of a model, factors to be considered include: cohesion between particles, density of bed material, viscosity, surface tension and density of fluid. If four of these five are negligible there is no difficulty in selecting the model scale. Models used in present study are of structures already tall in relation to their length, and vertical exaggeration is unnecessary. One model used was 21″ high and the other was 4.2″ high. Two different bed materials used, one a sand of 0.036″ size particles and the other with particles of 0.012″; both sands composed of uniform size grains. Comparisons made between results on the large and small model to test effect of scale. Observations on behavior of the two models indicated 30 min. to be most desirable time duration of a test. The flat apron as a protective device below a dam was found to suffer from scour at its lower end, almost regardless of its length, unless the energy were dissipated by steps, protective sills, deflectors, or a simple sloping sill. With deep tail waters the jet falling off of the dam is turned up and this type of flow pattern can be obtained when the apron length is less than the tail-water depth. Whatever the tail-water depth the importance of placing the apron well below the river bed cannot be stressed too highly. All experiments show that, provided the apron is sufficiently low and is equipped with a well chosen sill, scour can be reduced to an unimportant amount, or even eliminated, unless swirls in a horizontal plane are set up.—*H. E. Babbitt.*

New Light on Stability Problem of Earth Dams. LEO CASAGRANDE. Deut. Wasserwirtschaft **34**: 97 (Mar. '39). Until recently the position was that, while theory seemed to indicate stability for any sand embankment having an angle flatter than the natural one, regardless as to whether it stood in air or under water, yet observation had shown that when submerged cohesionless sands would sometimes lose all stability and flow away. Arthur Casagrande, at Harvard University, in '35, was the first to explain satisfactorily the role of porosity in submerged cohesionless materials like sands. (See J. Boston Soc.

Civil Eng., Jan. '36). Since then much valuable work has been done by him and under his direction and "critical porosity" has become an established concept. (See report of U. S. Engineer Office in Boston, Apr. '38). A detailed and illustrated account is given, with tables and graphs, of some of the Casagrande experiments. One very practical result has been the discovery that sands of dangerous porosity can be brought into a safe condition by rolling with a heavy roller, and that this operation is by no means an added expense, because, owing to the gain in stability, the quantity of material required is greatly reduced.—*Frank Hannan.*

Chart Gives Soil Weights. WALTER E. COWAN. Eng. News-Rec. **121**: 215 (Aug. 18, '38). As contribution toward closer approximation of loads on subsurface structures, nomograph is given from which wt. of soil in lb. per cu. ft. can be read if sp. gr. and moisture content are known. Two wts. are indicated, that in capillary state, i.e., where soil is saturated but is above ground water level, and that in submerged state, i.e., soil below ground water level, allowance being made for buoyancy. For approx. results, av. values of sp. gr. may be used as follows: soil 2.50–2.75; sand 2.65–2.75; clay 2.65–2.80. —*R. E. Thompson.*

Steel Facing for Dams. R. T. LOGEMAN. Civ. Eng. **9**: 7 (Jan. '39). In rock-fill dams with steel facings three prime materials are involved: (1) the fill to take the water pressure, (2) the steel face to form the water-tight seal, and (3) the concrete in the foundations and cut-off walls to carry the water seal to impervious material. Steel is an ideal material as it has strength, elasticity, and imperviousness. Such dams, known as the Bainbridge type, have been constructed for the Pikes Peak Power Co., near Victor, Colo., in a dam at Redridge, Mich., and in the Hauser Lake Dam near Helena, Mont. An advantage in the construction of this type of dam is that the steel can be placed after the fill is installed or in tiers on steel horses just in advance of the fill. Perhaps the most important feature of the steel facing is its assembly and welding so as to obtain both strength and watertightness which can be secured satisfactorily by welding. Riveted and calked facings will cost 22½% more than welded facings. In a consideration of timber, rubble masonry, concrete, and steel facings it is shown that the strength of concrete facing is one-sixth of that of steel and will cost 3% more.—*H. E. Babbitt.*

HYDROLOGY

Analysis of Run-off Characteristics. OTTO H. MEYER. Proc. A.S.C.E. **64**: 1769 (Nov. '38). Analysis of the characteristics of run-off hydrographs is outlined and revision of the current methods for the determination of stream flow from rainfall is proposed. Well known that run-off is not a function of rainfall alone but involves such factors as infiltration, evaporation, and surface pondage. If, after run-off has become constant, the rainfall cease, all water in surface detention soon runs off into stream beds, soaks into the ground, or evaporates. The writer found that $C_1 - t = C_2 \log Q$ in which, C_1 and C_2 are constants applicable to a particular drainage area; t is the time from the beginning of the storm, in days; and Q is the discharge in c.f.s. A

corollary to the logarithmic expression for storage run-off is that the discharge is directly proportional to the remaining storage. When a storm with duration less than the time of concentration occurs the shape of the hydrograph is affected. The hydrograph for a storm of any duration will follow the basic hydrograph until the cessation of the storm. The basic hydrograph may be synthesized from one resulting from a storm of known duration. A simple method is given for transposing a hydrograph to a location where no stream flow measurements have been taken. If a unit hydrograph is desired it can be computed from the transposed basic hydrograph as can distribution graphs from storms of any duration. The generally accepted method of reconstituting the hydrograph resulting from a group of storms is to add directly, the hydrographs resulting from the rainfall occurring in each unit of time, each one computed as if it were the run-off of an isolated unit storm, using the distribution graph. Sample computations are given for analysis of the concentration curve and for computation of a reconstituted hydrograph. *Discussion. Ibid.* **65**: 511 (Mar. '39). LEROY K. SHERMAN: Since introduction of the unit graph method, several improvements have resulted, and a keener appreciation of the value of interpreting the hydrograph has developed. Author has presented a useful review of run-off characteristics and has outlined certain original procedures. He may have developed a desirable principle that would effect an improvement over the unit graph method, but, in writer's opinion, this has not been demonstrated in the paper. RICHMOND T. ZOCH: From considerations stated by the writer it is possible to set up a differential equation and from it to find the exact mathematical expression which represents the rate of run-off as a function of the rate of rainfall in any given time. It has been shown that for a rectangular drainage area, using essentially the same assumptions that the author uses, the time of max. discharge is expressed by the function

$$t_c = c \log \left(e^{\frac{L}{cv}} + e^{\frac{t_0}{c}} - 1 \right) \qquad (23)$$

In this function t_c is the time of the crest of max. discharge, measured from beginning of rain; c is capac. of the soil to absorb water internally or as pondage; t_0 is duration of rainfall; L is distance from the gage to source of stream; and v is velocity of the water. Mathematical theory shows that the concept of the unit hydrograph is practically applicable when: (1) concentration time is appreciably greater than the duration of the rain and the drainage area is of such shape that the crest cannot precede the concentration time; and (2) duration of the rain is appreciably greater than the concentration time, regardless of the shape of the drainage area. Under other conditions, the application of the unit hydrograph will not yield reliable results. MERRILL BERNARD: Time of concentration is now more generally understood to be the time interval at the end of which all parts of the watershed are contributing to peak flow. However, it is known that on any particular basin rainfall may be so favorably concentrated over the lower principal tributaries as to create the peak of the hydrograph before outlying areas have produced and delivered effective quantities of run-off to the outlet. It is also evident that the concentration period cannot be a constant on any watershed. "Time contours" or isochrons would differ from contours as the former would be foreshortened

because of the higher rate of travel of the water after it has reached the principal channels. Concentration time may be expressed as the time required by the first water leaving a series of unit-areas along an isochron to reach the outlet; or it may be considered as the time taken by a series of unit-areas to discharge completely the run-off resulting from a unit-time rainfall. Variations in the concentration period are attributable to: (1) changes in the vegetal cover of the watershed, (2) changes in bank and channel growth, (3) the initial depth of water in channels, and (4) variations in the distribution of rainfall. *Ibid.* **65:** 686 (Apr. '39). FRANKLIN F. SNYDER: If the time of concentration for any area be agreed upon the results obtained by use of the unit hydrograph and the basic hydrograph will be identical. Assuming that a basic hydrograph can be agreed upon for any area there are several weaknesses in its analysis and synthesis as given by the author. Use of the recession coefficient eliminates about two-thirds of the work involved in unit hydrograph computations. It is probable that the author's synthesis of a hydrograph shows no superiority of accuracy as compared with the unit hydrograph procedure. W. G. HOYT: Through such detailed analyses as those described by the author there is accumulating a mass of valuable information relating to the characteristics of run-off resulting from precipitation. Much more hydrologic research with reference to run-off is needed.—*H. E. Babbitt.*

Forecasting Stream Flow from Snow Surveys. GEORGE D. CLYDE. Civ. Eng. **9:** 237 (Apr. '39). Storage of water as snow makes possible advance determination of probable water supply. Forecasting total supply over a given period, on the basis of snow surveys, is now well established, but determination of the probable discharge for any specific date during the critical runoff season is more difficult. Stream-flow forecasting based upon the percentage method assumes that precipitation is the most important factor and that losses can be grouped together and given a fixed value depending on the particular watershed. Snow-cover-runoff relationships are different on each watershed. A study of typical Utah streams not regulated by storage reveals a striking uniformity in the slope of their daily hydrographs during the falling stage and the critical low-water period. Found that rectangular hyperbolas could be drawn that would coincide almost perfectly with the forecast curves, but to keep their axes parallel to the axes of the hydrograph it was necessary to rotate them through a small angle. Result was a forecast equation of the form $y^2 + Axy - x^2 = B \pm C$, in which y is the discharge in c.f.s. at any date, and x is the time interval in days between date of forecast and date for which discharge is desired. A and B are fixed by the origin and rotation of hyperbola, and C is determined by the distance above or below the base of the hydrograph that the base of the hyperbola was found to be. The equation being a little awkward to handle, a graphical method of forecasting was worked out that would produce the same results.—*H. E. Babbitt.*

Errors in Water Engineering. GÜNTHER SCHLESINGER. Deut. Wasserwirtschaft **34:** 3 (Jan. '39). Author instances the regulatory work carried out on the Danube R. at Vienna in the seventies of last century. Main stream of the old unregulated Danube pursued a meandering course from west to east

at some little distance north of the city. On either side it threw off arms and branches, some of which reached into the city. It formed a huge, intricate labyrinth, the width of which, in the 25-mi. from Vienna down to the Hungarian frontier, varied at normal water levels from 2½ to 7½ mi. and, at flood-time, from 7½ to 9½ mi. The control plan adopted, not without opposition, was to confine the river for some ten miles of its course where it passes Vienna, to a single nearly straight channel, known as the Vienna cut (Wiener Durchstich), hoping, presumably, (1) to preserve Vienna from flood damage, and (2) to provide a good waterway. The inundation strip was limited to ½ mi. in width by levees. Main channel was provided with banks of loose stone and a wider channel for intermediate water levels was given similar banks. In the result, Vienna has remained free from flooding, but the waterway has given poor satisfaction and the damage inflicted upon forestry, husbandry, fishery, and hunting in the district below Vienna has been immense. The level of the Danube at Vienna is constantly changing. It has an extreme range of about 50′, but variations of from 6′ to 10′ within a few hours are not unusual. As it carries a tremendous burden of boulders, gravel, and sand at high water, it is capable upon a sudden drop in water level of depositing these in huge quantities almost without notice. Thus the whole river was blocked with gravel some few years ago at Deutsch-Altenburg, near the frontier, so that it took three weeks to clear it sufficiently to allow boats to pass. Hence it occurred that large deposits of gravel shifted the channel with nearly every flood. Devices introduced after long experience have improved matters somewhat. Conclusion is that every stream has its natural rhythm which should be deeply studied before embarking on improvement schemes.—*Frank Hannan.*

On Waves of Artificial Origin in a Natural Watercourse. D. G. Trossbach. Deut. Wasserwirtschaft **34:** 57, 108 (Feb., Mar., '39). Time and again do we find advantage taken of the occurrence of floods, either of natural or artificial origin, to note and record characteristics of the flood flow, or wave. Opportunity for study of flow fluctuations of moderate amplitude is not usual. Interest therefore attaches to certain conditions in the upper Danube which produce a more or less regular daily pulsation in the flow. In combination with this, there are government-maintained automatic water-level recorders at frequent intervals along the course of the stream, by means of which the diminishing intensity of the pulsations as they travel downstream is brought into clear relief until their gradual but final extinction at about 210 km. from their origin. The pulsations are caused by operation of three hydro-electric power plants by the city of Ulm on the Danube. The plants are all on the Danube and above the city. The stream-flow fluctuates rather widely and for this reason all three plants have turbine capacities which are for a great part of the year in excess of the available flow. But each plant has extensive impounding facilities and when the demand for power dies down at night, it starts to store a portion of the stream flow in its reservoirs, to be used next day to supplement the regular stream-flow at times when power demand is high. Among the observations of interest are noted the following: As a wave passes downstream, its height will decrease more rapidly than the volume of water accompanying it. Its flattening out is due much more to the influx of

tributaries than to adjustments taking place in the watercourse itself. This is easily understood when we remember that the tributaries are comparatively large; the Iller, for instance, which joins the Danube at Ulm, often carries the larger volume of water at the junction of the two. Also the tributaries are very numerous on both banks. The length of these waves is so great, in proportion to their height, that stream-line flow may be assumed. The velocity of wave propagation is always greater than that of the water itself. Of four formulas for wave propagation velocity which were tested, those of Boussinesq, Scott Russell, Bazin, and Forchheimer, the last agreed best with observations. —*Frank Hannan.*

Department of Water Control. BESOMBES. Ann. Serv. tech. Hyg. (Paris) ('37). Report of the work of the Loire valley laboratory at Cosne. Measurements of the alkalinity of the rivers Loire and Allier before and after their confluence show that the waters are not completely mixed 60 km. below the point of confluence.—*W. P. R.*

Fifty Years of Water Resources Study. JOHN C. HOYT. Eng. News-Rec. **122:** 396 (Mar. 16, '39). History of water resources studies in U. S. is reviewed briefly. Systematic measurement of flow of streams by federal government was inaugurated late in 1888 by establishment of instruction camp on Rio Grande at Embudo, N. M., to develop methods, instruments and equipment. Following yr., 11 men were assigned to various drainage basins in arid West. Work on nationwide basis was started in 1895 with appropriation of $12,500. Records of flow now available at over 7200 stations, 3800 of which are now in operation, 70% being equipped with stage-recorders. Appropriation for '39 is $1,050,000 and this amount is augmented to over $3,000,000 by state and municipal co-operation, by emergency funds and by transfers from other federal bureaus.—*R. E. Thompson.*

The Rainfall of the British Isles. J. GLASSPOOLE. Wtr. & Wtr. Eng. (Br.) **40: 77** ('38). Describes work of the British Rainfall Organization which is concerned with collecting and collating information about the rainfall of the British Isles. Founded in 1860 and from the accumulation of data since that date, earlier records have been interpreted and it has been possible to prepare a series of monthly values of rainfall from 1727 up to the present year, and to construct maps showing the distribution of annual and monthly rainfall over the British Isles. The value of this information in forecasting rainfall and in estimating the yield of catchment areas to be utilized as sources of water supply is explained. A bibliography containing 20 references to recent investigations dealing with the rainfall of the British Isles is appended.—*W. P. R.*

Deriving the Local Rainfall Characteristics for Sewerage Purposes from the Automatic Rainfall Record. GUNNAR ÅKERLINDH. Teknisk Tidskrift, Uppl. E (Stockholm) **69:** 45 (Apr. '39). Author believes his results may be of interest wherever, as is frequently the case in Sweden, continuous automatic rainfall

record is available. With a 20-year record, guess-work may be eliminated. The first step is to select units for duration and intensity, small enough for accuracy, but not so small as to involve excessive labor. For duration, his indivisible units are 5-minute intervals. For intensity, his working unit is 10 litres per second per hectare (l./s.ha.), but intensities under 30 l./s.ha. are disregarded as being negligible. Each 0.3 mm. of rainfall per 5 min. is equal to 10 l./s.ha.; rainfalls of less than 0.9 mm. per 5 min. are disregarded. Each rainfall in turn as it appears on the record is given a number and tabulated; the reading at the end of each 5 min. is set down to 0.1 mm.; by subtraction, the rainfall for the 5 min. in mm. and tenths is determined; and this is then reduced to intensity. The 5-min. intervals are classified in order of intensities, those of equal intensity combined to give units of longer duration, and the whole rainfall is thus ready for further tabulation according to duration and intensity. In the final 20-yr. tabulation at Norrköping ('19–'38), 943 items thus obtained from the various rainfalls were classifiable under 18 durations (5, 10, etc. to 90 minutes) and 25 intensities (30, 40, etc. to 270 l./s.ha.), the durations being in vertical columns and the intensities in horizontal rows; at each intersection were entered the total number of items corresponding. Based upon this tabulation, development of graphs of rainfall characteristics was not difficult. Double logarithmic rulings were found suitable. Examples are: (1) intensities as ordinates, frequencies as abscissae; series of curves for the various durations showing how often in the 20 yrs. rainfall of a given duration exceeded the several intensities; (2) intensities as ordinates, duration as abscissae; series of curves (parallel straight lines) for the frequencies once, twice, 5 times, 10 times, 20 times, 40 times, in the 20 yrs.; (3) intensities as ordinates, durations as abscissae, total yearly average duration during the 20-yr. period of rainfalls of the different intensities; (4) intensities as ordinates, rainfall (cu. m. per hectare) as abscissae; total yearly average rainfall at the various intensities; (5) intensities as ordinates, frequencies as abscissae, average frequency during the year of rainfalls of the various intensities; (6) intensities as ordinates, durations as abscissae, normal duration for a rain of any given intensity (or vice versa); (7) intensities as ordinates, durations as abscissae, longest continuous duration observed in the 20-yr. period for the different rainfall intensities; and (8) intensities as ordinates, rainfall (cu. m. per hectare) as abscissae, normal precipitation per rainfall at the various intensities. Care and judgment are called for in obtaining the proper smooth curve in each case; it is believed the final results as presented are highly reliable.—*Frank Hannan.*

Arkansas Earth Dam Fails During Construction. ANON. Eng. News-Rec. **122**: 535 (Apr. 27, '39). About 125′ of earth dam being built in Short Mountain Creek as water supply project for Paris, Ark., was washed out Apr. 16 when record-breaking rainfall of 5.35″ in 15 hrs. caused creek to rise 5′ in 30 min. Municipal pumping plant below dam was seriously damaged and town was without water for about 3 days. Dam, 740′ long earthfill with design height of 57′, was about 75% completed. Damage to dam is estimated at $15,000–18,000.—*R. E. Thompson.*

Hydrology of the Great Lakes. A Symposium. Proc. A. S. C. E. **65:** 584 (Apr. '39). *Typical Quantitative Analysis as Applied to Lake Superior.* C. R. PETTIS. A method of making quantitative analysis of the inflow and outflow of the lake. Methods for measuring the various factors are discussed at length. *Evaporation Experiments.* HAROLD C. HICKMAN. The evaporation experiments reported were conducted at Duluth, Kewaunee, Detroit, and Buffalo for the purpose of providing a basis for estimating evaporation from the Great Lakes. The readings have been analyzed and plotted on two charts from which estimates of daily or monthly evaporation can be made. Indications are that the effect of wind is fundamentally different than that indicated by the common evaporation formulas. Rate of evaporation from open water when the air temperature is below freezing has been investigated for the first time. The 3 principal factors affecting evaporation are air and water temperatures and wind velocity. The observations have been analyzed by comparison with a modification of Dalton's law $E = K\ (V - v)\left(1 + \frac{W}{c}\right)$ in which K is a constant for particular conditions; W is the mean velocity of the wind; c is a coefficient expressing the effect of the wind; and $(V - v)$ represents the saturation deficit of the atmosphere. The experiments indicate that evaporation continues despite the indication of the formula that it becomes zero when $(V - v)$ becomes zero.—*H. E. Babbitt.*

LIMNOLOGY

A New Method of Weed Control in Lakes and Reservoirs. HERMAN SEYDEL. W. W. & Sew. **85:** 688 (Jul. '38). "Benoclor 3", a chlorinated hydrocarbon, was sprayed under water in a reservoir. Weeds killed without creating bad odor at cost ranging upward from $19 per acre. Annual treatment seems to be all that is required. There appears to be no serious danger to fish. Treatment caused taste which must subsequently be removed.—*H. E. Hudson, Jr.*

Mechanical Hyacinth Destruction. W. E. WUNDERLICH. Milit. Engr., (Wash.) **30:** 5 ('38). The water hyacinth has spread rapidly in Florida since it was introduced in 1884, and continual destruction is necessary to keep the waterways clear. The most usual method of destruction is spraying with an arsenical solution but there are dangers to men and animals in the use of this poison. In consequence a barge was built carrying an apparatus which destroys the vegetation mechanically by crushing it between rollers; the crushed fragments sink and are decomposed. Details of the apparatus and a 15-day test under actual working conditions are described.—*W. P. R.*

Filamentous Algae and Their Control. R. WEIMANN. Z. Fischerei **35:** 211 ('37); Wass. u. Abwass. **35:** 383 ('37). In many ponds used for breeding carp in Silesia, filamentous algae, especially *Cladophora*, develop in very large quantities. A net-work may form over the whole pond. This alga develops most vigorously in hatching ponds, possibly because the young fish are not capable of stirring up the bottom of the pond. One method of controlling *Cladophora* is to introduce one- or two-year old carp. Experiments with

"lime-nitrogen" (crude calcium cyanamide), copper sulfate, caustic lime, and calcium chloride showed that "lime-nitrogen" appeared to be best suited for chemical control of the algae.—*W. P. R.*

Examination of the Waters of North Craig Reservoir. W. DUNBAR. Wtr. and Wtr. Eng. (Br.) **40:** 262 (May '38). Reservoir has capacity of 56 mil. gal., max. depth of 13′ with large areas of shallow water. In '23 large growth of *Anaboena* appeared giving water bitter taste and strong smell. Copper sulfate (1.2 lbs. per mil. gal.) treatment gave no apparent change, later 1.6 then 2.0 and finally 3.0 lbs. per mil. gal. were applied all in space of 3 mos. Month later water absolutely free of *Anaboena* and copper sulfate content at top of reservoir was 0.43 lb. per mil. gal. This treatment has been continued every year and at times copper sulfate content of reservoir was 3.5 lbs. per mil. gal. Growth appears every year but not in any intensity, if there is mild weather in spring growth appears 2 mos. later and rises to surface suddenly, almost invariably after thunderstorm. Copper sulfate appears to have no effect on trout life. In '31 chlorination of water before entering reservoir was started. Some mos. later a protococcus unicellular algal growth appeared which passed filters easily. On running raw unchlorinated water into reservoir growth disappeared. From then onwards regular microscopic investigation of water undertaken to study seasonal distr. of organisms and to arrest troublesome ones at outset. Storage reservoirs have dominance of diatoms, e.g. *Asterionella* and *Synedra* between late Apr. and early June accompanied largely by protozoa and possibly crustaceans, e.g. *Cyclops* and *Daphnia*; green algae between June and Aug.; blue green algae, e.g. *Anaboena*, from late July rising to peak during Oct. and early Nov. and being again followed by diatoms and protozoa.—*W. G. Carey.*

Algae Straining. JOHN H. KUESTER. W. W. and Sew. **86:** 112 (Mar. '39). Self-cleaning drum-type screen is used to strain weeds and algae from water prior to filtration at Menasha, Wisconsin. 80 mesh wire cloth is employed.—*H. E. Hudson, Jr.*

Some Factors Relative to Fish Culture and Fisheries Management. A. D. ALDRICH. Southwest W. W. J. **20: 7:** 31 (Oct. '38). Fish are considered as crops and same principles apply in their production as to that of plants and animals. In hatcheries 5 lbs. of feed is min. requirement to produce a 1 lb. fish, and 3 lbs. per yr. to maintain a 1 lb. fish, and a good pond should produce 100 lbs. of fish per yr. Av. lake will produce ½ of above amounts. Lacking plants and plant foods many artificial lakes are not stable habitat for fish. Common error is to overstock and to use unadaptable species. A new artificial lake has much food from vegetation covered by water and, by the second yr. following stocking, the lake is full of good uniform sized fish. The third year number of fish decrease markedly because the organic substance is exhausted and the older fish cease eating insects and must have minnows or other fish. By the fourth and fifth yrs. aquatic plants are established to provide shelter for fish and forage for insects building up natural foods and protection.—*O. M. Smith.*

Physical and Chemical Characteristics of Cultus Lake, British Columbia. W. E. RICKER. J. Biol. Board Canad. **3**: 363 ('37). The first paper of a series which will deal with the factors influencing the survival and behavior of sockeye salmon (*Oncorhyncus nerka*) in Cultus Lake, British Columbia. In this paper the physical and chemical features are considered. The situation, climate and vegetation of the lake and its surroundings and the configuration of the shore and bottom, bottom deposits, volume of flow, and transparency and color of the lake are described. The temperature gradients at different times of the year were examined in detail. The lake does not usually freeze over in winter and there are only two well-marked seasonal conditions—winter circulation and summer stagnation. A thermocline is established about May and lasts until about Dec. The amount of heat necessary to raise the water from the min. temp. of winter to the max. temp. of summer is exceptionally low owing to the generally equable climate of the region. The temperature of the hypolimnion rises gradually during the summer and the manner in which it is heated is discussed. Author considers that direct penetration of solar radiation is the only satisfactory explanation. Changes in the contents of dissolved oxygen at different levels during the year were also examined. The epilimnion is supersaturated during the early months of the year; in Sept. and Oct. the oxygen content is very close to the saturation value and there is a decrease of saturation in Dec. The hypolimnion is saturated at the beginning of the year; in its upper layers a steady concentration is maintained during the summer but the lower layers contain decreasing quantities of dissolved oxygen as the year progresses, though there is always sufficient oxygen for the sockeye salmon. The contents of bicarbonates, carbon dioxide, nitrates, nitrites, phosphates and silicates, and the hydrogen ion concentration were also determined.—*W. P. R.*

The Oscillatoria Disease in Our Lakes. The Biology and Chemistry of Some Brandenburg Lakes. R. CZENSNY. Chem. Z. **62**: 469 ('38). *Paper before Water Chemistry Sect. Verein Deutscher Chemiker, June '38.* Since '29 a biological change has taken place in a series of three lakes in Brandenburg and has had a harmful effect on their value as fisheries. Normal plankton of the Havel lakes has been replaced by a yellowish-green growth consisting almost entirely of two species of *Oscillatoria*. Lower layers of water have been depleted of oxygen and large quantities of hydrogen sulfide formed. Lakes under investigation form a series of lakes on the Havel. In the dry period since '29 natural ground water springs have dried up and rise and fall in the lakes has been very limited. Boundary between the surface layers rich in oxygen and the deep water containing hydrogen sulfide very clearly marked. Its position is not affected by rain or wind; a sudden fall in temperature will cause mixing but stratification is restored on reappearance of warm weather. As formation of hydrogen sulfide begins in the spring and lasts until well into autumn fish cannot live in the deeper regions during their season of growth. The mud in the lakes is colored yellow and, though its chemical composition differs little from that of the normal mud of Havel lakes, its pH value is lower.—*W. P. R.*

Studies in the Periodicity of the Algae in Veauchief Ponds, Sheffield. EDNA M. LIND. J. Ecol. (Br.) **26:** 257 ('38). Investigation was made to det. periodicity of certain algae and corresponding changes in phys. and chem. condition of water. *Ulothrix*, diatoms and *Spirogyra* reacted favorably to presence of nitrate; *Cladophora*, *Rhizoclonium*, *Oscillatoria*, *Oedogonium* and *Euglena* reached max. in summer when nitrate was low. *Volvox* received severe check when nitrate rose suddenly, but at time of low nitrate content it reproduced sexually. Albuminoid ammonia was at max. when nitrate was at min., in late summer, and at this time *Cladophora*, *Rhizoclonium*, *Oscillatoria* and *Euglena* were plentiful. Fluctuations in P_2O_5 were not closely related to algal periodicity. Effects of other factors such as sunshine, rainfall, germination of resting spores and competition were also studied.—*C. A.*

The Phytoplankton of the River Shannon and Lough Derg. R. SOUTHERN AND A. C. GARDINER. Proc. R. Irish Acad. **45:** B: 89 ('38). Describes a quantitative investigation, made in '22, of the phytoplankton in the river Shannon at Portumna and in Lough Derg into which the river flows. Methods for collecting and concentrating samples of the plankton are discussed. Concluded that nets cannot be used for quantitative work as their efficiency varies with age. The seasonal variations of the different groups and of a number of individual species are discussed. A number of species persist all the year round. There was not very much difference between the flora of the river and of the lake, although there were many more Crustacea in the lake. The phytoplankton of the Shannon may be regarded as limnetic which may be due to the influence of Lough Ree, a lake further up the river.—*W. P. R.*

A Preliminary Study of the Phytoplankton in Lake Sarah (New Zealand). E. A. FLINT. J. Ecol. (Br.) **26:** 353 ('38). Abundance of *Dinobryon sertularia* occurred prior to, or coincided with, diatom max., and was characterized by high SiO_2 content and low N/P ratio. Increase of phytoplankton in spring coincides with rise in temp. and pH and is accompanied by fall in O content; summer maxima follow highest pH and temp. Fall in SiO_2 content between Jul. and Sep. may be correlated with growth of *Asterionella gracillima*. Fact that this max. occurs when P_2O_5 is high and N/P ratio is low supports conclusion of Pearsall that growth of *A. gracillima* in Ullswater is favored by these conditions. *Aphanocapsa* is most abundant at end of summer when high organic content of water occurs, which is in accordance with occurrence of blue-green algae in plankton of other waters.—*C. A.*

Mineral Content of the Lake Waters of Northeastern Wisconsin. C. JUDAY, E. A. BIRGE AND V. W. MELOCHE. Trans. Wis. Acad. Sci. **31:** 223 ('38). In analysis of the surface waters of 519 lakes of the Highland Lake District of northeastern Wisconsin, it was found that amt. of silica ranged from 0 to 25.6 mg./liter; more than 50% had less than 1.0 mg./liter and about 87% less than 5.0 mg./liter. In some cases there was little or no increase in silica with increasing depth in the summer period of stratification, while in others there was a marked rise in the lower water. Iron content of surface waters of 74 lakes varied from a trace to 2.0 mg./liter; 3.0 to 6.0 mg./liter were noted in

lower water of some of the lakes, especially where the bottom stratum had considerable amt. of free CO_2 and little or no dissolved O. Under anaerobic conditions most of the Fe was in the ferrous state. Mn found only in very small amts. (0.003–0.023 mg./liter) in the surface waters but there was definite increase with increasing depth in some of the lakes. The Ca content of the surface waters of 358 lakes ranged from 0.13 to 18.8 mg./liter; 52% of them had less than 5.0 mg./liter and 86% less than 10.0 mg./liter of Ca. The Mg found in the surface waters of 290 lakes varied from 0.1 to 6.5 mg./liter; 36% of them had less than 2.0 mg/liter and 81% less than 5.0 mg./liter. There was a wide range in the ratio of Ca to Mg; in 2 cases surface samples contained twice as much Mg as Ca; in others the 2 elements were present in about equal amts., while in still others the quantity of Ca was 2 to 6 times as large as that of Mg. Large percentage of the waters contained unusually small amts. of Ca and Mg, so that they may be regarded as very soft, some of them as extremely soft. From a quant. standpoint, the bound CO_2 was more closely correlated with the amt. of Ca than with that of Mg. Quantity of F ranged from 0.1 to 0.5 mg./liter in the 24 lake, spring and well waters that were analyzed. The chloride content of 474 surface waters was small, ranging from 0.1 to 4.5 mg./liter; in general it was substantially same from surface to bottom in the various lakes. The surface waters of 234 lakes contained 0.7 to 7.8 mg./liter of sulfate; in some lakes amt. of sulfate was about same at surface and bottom, but in others there was somewhat larger quantity at bottom than at surface. Surface water of 74% of the lakes in summer contained no ammonia N or only a trace; an addnl. 22% yielded 0.01 mg./liter. Little or no ammonia N found in the lower water of a no. of lakes, while varying amts. were noted in the bottom stratum of others, especially in lakes which had little or no dissolved O in this stratum. With 5 exceptions no nitrite N was present in the surface waters but small amts. were observed in the bottom stratum where little or no dissolved O was found. The nitrate N ranged from 0.004 to 0.070 mg./liter, with mean of 0.018 mg./liter, in the surface waters of 472 lakes. In some cases the nitrates were rather uniformly distributed from surface to bottom in summer, while in others there was a more or less marked increase in the lower water. Nitrate reduction took place in the bottom strata of some of the lakes.—*C. A.*

Sodium and Potassium Contents of Wisconsin Lake Waters and Their Residues. D. Lohuis, V. W. Meloche and C. Juday. Trans. Wis. Acad. Sci. **31**: 285 ('38). Total alkali content of a group of 61 drainage and 30 seepage lake waters and their residues were detd. by polarograph; Na was detd. by the Zn uranyl acetate method and K by difference. Results tabulated for color,—free and bound, CO_2, pH and sulfate. Following comparisons are made, summary of which can best be made by reference to the numerous figures accompanying this report: distribution of total alkali in drainage lakes on the basis of p.p.m. and percentage of alkali in the residues; variation of alkali with the color of the water; variation of alkali with the bound CO_2 of the water; variation of alkali with the sulfate content of the water; variation of the ratio, Na/K, for the various lakes in the drainage group examd. Authors point out that although the drainage lakes are not hard water bodies, yet they do

contain more dissolved material per liter than do the seepage type, a relationship holding also for total alkali. Waters of the drainage lakes for most part show a Na-K ratio of approx. 1:1 with a possible Li correction lowering it to less than unity at the expense of the Na. For the relatively small no. of seepage lakes which were examd., this ratio is for the most part less than 1:1; same reservations as to accuracy here also pertinent.—*C. A.*

Amount and Distribution of the Chlorophyll in Some Lakes of Northeastern Wisconsin. ZYGMUNT KOZMINSKI. Trans. Wis. Acad. Sci. **31:** 411 ('38). By photometric measurement in the region 6200–6800 A., the chlorophyll content was detd. in the acetone ext. of the plankton taken during the 2 summer months from various depths in 17 northeastern Wisconsin lakes of very different and relatively very well known limnological characters. The problem of horizontal differentiation in chlorophyll content at 1-m. depths above the bottom at different places was studied on only one lake. A large variation (1-386.2 mg./cu. m.) was found in the vertical distribution of chlorophyll in the lakes studied, 5 different types of stratification having been distinguished. There were distinct concn. differences (1.4–5.2 mg./cu. m.), depending on depth of lake at point investigated, in water layers lying immediately above the bottom. Mean concn. of chlorophyll in a water column from surface to bottom in the lakes studied was between 1 78 and 165.54 mg./cu. m. The increase in mean chlorophyll value in these lakes appeared to parallel approx. the increase in productivity of the lakes. Conclusion: The relatively large amts. of chlorophyll found in the deepest layers of some lakes must be inactive photosynthetically. Possible causes are considered for the different types of chlorophyll stratification, and the influence of light conditions on its vertical distribution is discussed. Tables accompanying this report contain data showing not only the chlorophyll concn. but also several other important limnological characteristics of the lakes investigated.—*C. A.*

A Biological Growth Research on the Waters of the Great Holy Lake with Special Reference to Its Iron Content. KARL F. KRIEGSMANN. Abhandl. Landesmuseum Prov. Westfalen, Museum Naturkunde **9:** 2: 1 ('38). Detailed study of effects of seasonal changes and other factors upon chem. compn. of water and plankton growth in Great Holy Lake (Westphalia) is given. Amt. of assimilable P, not Fe, is a limiting factor as regards plankton growth. No very definite conclusions are drawn. References.—*C. A.*

On the Relation Between the Oxygen Deficit and the Productivity and Typology of Lakes. G. E. HUTCHINSON. Int. Rev. Hydrobiol. **36:** 336 ('38). Discusses methods of expressing the oxygen deficit in the hypolimnion of lakes, and its use for predicting the productivity of lakes. The real oxygen deficit is taken to be the apparent oxygen deficit *plus* the oxygen required to combine with the substances in the water which would be oxidized in the presence of abundant oxygen. The rate of development of this deficit per unit area is regarded as an indication of productivity. This theory is discussed with reference to the work of various investigators on lakes in different parts of the world.—*W. P. R.*

Oxygen Production by the Diatom, Coscinodiscus Excentricus, Ehr., in Relation to Submarine Illumination in the English Channel. P. M. JENKIN. J. Marine Biol. Assoc. United Kingdom **22**: 301 ('37). Photosynthesis in sea was estd. by lowering bottles of medium (Miquel Sea Water) and diatom growth into sea at different levels, O production of the pure cultures then being measured by Winkler method. "Total O production" was obtained by adding to "net" amt. of O produced in the light an amt. of O equal to av. amt. consumed by respiration in dark. This was based on view that plants respire at const. rate whether in dark or exposed to light. Factors other than light, which might affect rate of O production, were negligible. It was found that diatoms could use energy for photosynthesis equally well in all parts of spectrum. Utilization of available energy amounted to about 7%. Analysis of diatoms gave ratio of C:P:N of 32:1:5.5. Ratio for Fe:P was about 1:1.—*C. A.*

Limnological Investigations of the Crustacean Plankton in the Schleinsee and in Two Small Ponds. H. v. KLEIN. Int. Rev. Hydrobiol. **37**: 176 ('38). An examination of the crustacean plankton in the Schleinsee was carried out in '34. Physical and chemical investigations also made, including determinations of temperature, depth of visibility, content of dissolved oxygen, hardness and pH values at different depths. No full vertical circulation occurred in the spring as surface layers heated rapidly. Depth of visibility least in June and greatest in Jan. After the ice had melted dissolved oxygen in the upper layers increased and at 4–5 m. up to 145% saturation was found in April and May. Excess oxygen in the surface layers will be liberated into the atmosphere. At a depth of 10 m. the oxygen content was at a minimum in the summer. Carbonate hardness determined with hydrochloric acid, using methyl orange. At the surface the hardness fell gradually from Apr. to Aug. and then rose a little until the autumn circulation; at a depth of 10 m. the curve is reversed. The pH value was highest (8.5) at the surface in July and lowest (7.15) at a depth of 10 m. in Oct. Hydrogen sulfide occurred at 10 m. during the summer stagnation. The numbers of crustacea are at a minimum in the winter, rise a little in Feb., fall again and then rise to a maximum in Aug. During the summer stagnation the crustacea are chiefly found in the upper layers of the metalimnion but after the autumn circulation no stratification was noticed. The distribution of a number of species is discussed in detail. In two small ponds the period of maximum development of crustacea was considerably shorter than in the Schleinsee.—*W. P. R.*

The Maschsee and Its Biology. R. KOLKWITZ. Ber. dtsch. Bot. Ges. **56**: 58 ('38). The Maschsee is an artificial lake constructed two years ago in Hanover to give partial control of flow of the river Leine. The lake is 2.4 km. long, 400 m. wide and about 2 m. deep. The water is pumped from the Leine and passes through screens and rapid filters of fine gravel. The lake is eutrophic in character and contains a rich plankton. There is a sufficiency of oxygen in all layers. During '38 three plankton organisms appeared in large numbers for the first time; these were a form of the diatom *Coscinodiscus subtilis, Ceratium hirundinella,* and *Oscillatoria Bornetii.* There is no region of

tall water plants round the border of the lake, but only some filamentous algae, chiefly *Cladophora* with a little *Stigeoclonium Vaucheria* and *Oedogonium* and various diatoms. Weeds growing on the floor of the lake include four species of *Potamogeton, Elodea canedensis, Polygonum amphibium, Ceratophyllum demersum* and *Myriophyllum spicatum.* As these plants interfere with sailing and motor boats on the lake they are mown down at intervals by an implement towed by a boat. Odors have been caused by the development of large amounts of *Oscillatoria.* In the summer of '36 there were large numbers of *Chironomus* larvae in the lake, which with *Daphnia* provided food for carp. Stickleback, rainbow trout, tench, pike and great pike-perch live in the lake. Variations in the biology of the lake are to be expected for some time.—*W. P. R.*

The Importance of Exchange Processes between Sludge and Water for the Cycle of Materials in Waters. W. OHLE. Chem. Z. **62**: 469 ('38). *Paper before Water Chemistry Sect. Verein Deutscher Chemiker, June '38.* It has been shown that the composition of inland waters is affected by oxygen content and by oxidation and reduction processes. With low concentration of oxygen the concentrations of carbon dioxide and hydrogen sulfide increase. These two gases affect the exchange processes between sludge and water. It has been shown in the laboratory that under conditions poor in oxygen, the ratio of iron to manganese is less than unity in water rich in lime and greater than unity when little lime is present. This difference is all the more important because phosphates form almost insoluble compounds with iron, while manganese, at least under alkaline conditions, has not this effect. In a water rich in lime the phosphate content is thus not so likely to be depleted. The solubility of various substances is discussed. Nitrates are adsorbed by silica gels and ammonium ions are removed by organic materials and by silica gels. Frequently this is due to adsorption but chemical compounds may be formed.—*W. P. R.*

Sampling Lake Deposits. B. M. JENKIN AND C. H. MORTIMER. Nature (Lond.) **142**: 834 ('38). Describes apparatus for taking samples of deposits from bottom of lakes without compressing or distorting them. Apparatus is lowered from a boat on a single cable. A sampler used in Windermere collects cores 4′ long, and, by using extension tubes, deposits 9′ deep were examined.—*W. P. R.*

Aquatic Insects. J. CLEGG. Marshall Press Ltd., London. 30 pp. A brief description of insects, visible to the naked eye, which spend a part or all of their life in water, and directions for collecting and keeping specimens.—*W. P. R.*

HEALTH AND HYGIENE

Summer Typhoid. ANON. Philadelphia Dept. of Pub. Hlth. Quarterly Bull. 14 (Apr.–Jun. '38). 60% of the number of cases of typhoid in Philadelphia are found to have been contracted outside of the city. The local rate compares favorably with the best American and Continental cities. Immunization is recommended for travelers and vacationists.—*P H. E. A.*

A Dog as Source of Paratyphoid Infection. K. E. MAGNUSSON. Ztschr. f. Hyg. u. Infektionskr. **121**: 136 ('38). An account is given of an outbreak of enteric fever affecting four persons in a small isolated village in Sweden. The patients suffered from fever, diarrhoea and prostration, and their serum agglutinated *Bact. paratyphosum B*. The infection was traced to a dog which had come from another village a week previously.—*B. H.* (*See also* J. A. W. W. A. **31**: 737 (Apr. '39)).

Attempts to Sterilize Paratyphoid Carriers by Hexamine and Sodium Dehydrocholate. R. MACCOLINI. Biochim. e Terap. Sperim. (Milan) **25**: 489 ('38). Experiments devised to test the curative treatment of enteric carriers by means of drugs are of interest in that, if negative, they prevent others wasting time on repetition of them. Author used a strain of *Bact. paratyphosum B* isolated from a fecal carrier. Its relative low degree of pathogenicity for rabbits enabled large doses to be given. Ten were used for the test and ten others for control. Procedure was to give within 20 days six injections of an 18–24 hour broth culture at 37°C. in increasing doses, viz. 0.0005 cc., 0.005, 0.05, 0.5, 1.0 and 1.5 cc. A week after the last injection each received intravenously 1.0 cc. of 20% hexamethylene tetramine in physiological saline followed at once by the same amount of the same strength of sodium dehydrocholate. Seven such were given in 14 days and on the seventeenth day the animals were killed and cultures put up from the spleen, kidney, urine, liver and bile. Seven of the controls gave a growth from the bile, the other sources being negative. Of the test animals, five gave a growth from the bile and one a growth from the urine. In other words the drugs were ineffectual for the end desired.—*B. H.*

Glasgow Experience of Increased Dysentery Prevalence. E. BLOCH. Brit. M. J., p. 863 (Apr. 16, '38). Dysentery notifications in Glasgow between '19 and '34 averaged 56.3 annually. Between '35 and '37 annual total of institutional infections rose from 42 to 145 and annual total of cases averaged 215.3. No apparent association between increased prevalence of dysentery and that of other diarrhoeal diseases. Dysentery infections appear to be most prevalent in the third quarter of the year, although this tends to be obscured by institutional outbreaks. Probable that many mild and bacteriologically unproven cases remain unnotified. Food, e.g., milk and ice-cream, has been incriminated or suspected in both Sonne and Flexner outbreaks, and in both institutional and non-institutional outbreaks. In one class of institutional outbreak a definite spread from a previous case can be recognized, in the other the cases appear sporadically and more than one type of organism may be isolated. No special sex incidence revealed. Among 646 cases occurring in '35–37, 306 occurred below age of 15, and 340 cases above that age, and in cases occurring at home those under 15 outnumbered the others. In this series 30 deaths occurred, chiefly among infants and the elderly. Majority of cases probably still due to Flexner strains of the dysentery bacillus, and in period '29–'36 positive specimens numbered 413 Flexner as compared with 278 Sonne. Although one type of organism usually predominates in any one group it is not uncommon to find different types and strains associated in a multiple focus.

What is described as the first large institutional outbreak of Sonne dysentery in Glasgow occurred from Nov. '37 to Jan. '38. No definite evidence of spread by food, milk, or water, but it was considered important to devote attention to the methods of cleansing ward food utensils, especially milk containers, and to scald ward milk supplies.—*W. P. R.*

Paradysentery (Sonne) Investigations. S. ROHLEDER. Ugeskr. f. Laeger. **100:** 818 ('38). This Danish study undertaken in '36 and '37 with object of ascertaining how often the clinical picture of paradysentery resembles that of a simple, non-specific, acute, infectious gastro-enteritis lasting only a few days, with or without fever, and without blood and mucus in the stools. General practitioners in Rohleder's district were requested to send specimens of feces and urine in every case of acute gastro-enteritis to the State Serum Institute. After weeding out several cases unsuitable for analysis, there remained 129 patients in 73 households. Of 118 cases in which Sonne's bacillus was found, 72 had run clinical course indistinguishable from simple gastro-enteritis. Hence author's conclusion that the differential diagnosis is in practice quite impossible in many cases in the absence of bacteriological examination of stools and urine. He found that, even during an epidemic, it was common for only one or two members of a household to show clinical signs, whereas several other members of same household would prove to be at least temporary hosts of Sonne's bacillus. In about 58% of his cases Sonne's bacillus could no longer be found within a week of cessation of acute manifestations of the infection. In practically every case, bacteriological report was negative after two mos. In about 90% Sonne's bacillus was found only in stools, and in about 6% urine proved to be infected. Most exceptional for both stools and urine to be infected simultaneously. Author discusses the indications for a bacteriological examination of the stools and urine in cases of gastro-enteritis, and outlines measures to be adopted when bacteriological report is positive.—*W. P. R.*

Epidemic Nausea and Vomiting. ANON. (London correspondent) J. Am. Med. Assoc. **112:** 1089 (Mar. 18, '39). "In 1935 Danish writers described under the name of epidemic nausea what appears to be a new disease." The article reviews reports of outbreaks of similar characteristics which have occurred in England. Chief symptoms are vomiting, nausea, giddiness and diarrhea. Disease is regarded as "air borne and probably infectious." In referring to an outbreak of 45 cases in a group of 85 at a girls' school, it is stated that no organisms known to cause gastro-enteritis were found and, further, that the greatest argument against food or water contamination was the type of spread in families or institutions from the first patient.—*John H. O'Neill.*

The Amebiasis Problem. EDWIN S. KAGY. The Military Surgeon. **83:** 2: 158 (Aug. '38). Studies by the U. S. Medical Corps indicate the gravity and urgency of a very real public health problem in amebiasis. Nature and scope of problem delineated. Amebiasis, of which amebic dysentery is only a part of the clinical picture, probably exists throughout the world; wherever

sought by competent workers it has been found. As a result of studies covering every section of the U. S. it has been estimated that between 5% and 10% of the population of this country probably harbors *Endamoeba histolytica*. Although more prevalent in tropical regions it has been found wherever sought in the temperate zone. Clinically, persons infected may be divided into four classes in which symptoms vary from none appreciable (the so-called healthy carriers) to those accompanying acute or chronic amebic dysentery. Pollution of food or drink with feces containing cysts of *Endamoeba histolytica* allows transmission of amebiasis. Such contamination may occur through an infected water supply; through the use of night soil in fertilizing garden truck; through handling food and drink by infected persons; through fly droppings, and in other ways. Although food handling is held to be the most important means of transmission in communities with a satisfactory water supply, contamination of water supplies is thought to operate just as frequently and to result in an even greater number of infections where the water supply is obtained from dubious sources.—*P. H. E. A.*

Drinking Fountains. PAUL MENSING. Gesundheits-Ing. **62:** 106 (Feb. 18, '39). The development of drinking fountains is discussed and a new type described, in which the water nozzle is completely covered by an enamel shield in which only a hole exists for the water jet. Conditions to be met by a sanitary drinking fountain are summarized: (1) The fountain shall always furnish fresh cool water. (2) Its nozzle shall be protected against rust, dirt, dust, the possibility of touching it with the mouth or the hands and against mechanical damage. The nozzle shall not be flooded if the sewer connection should clog. (3) Water that cannot be taken up with the mouth shall not fall back on the nozzle. (4) The water stream for drinking shall be of low pressure, uniform in flow and not too sharp. (5) The valve shall close automatically. The regulating valve shall allow a quantitative limit to the flow. (6) The outside of the fountain shall be smooth and with as few projecting parts as possible to avoid harm to the user and to facilitate cleaning.—*Max Suter.*

Disapproved Plumbing Fixtures. ARTHUR B. CRONKRIGHT. W. W. and Sew. **85:** 801 (Aug. '38). Summarizes experiences in plumbing surveys in Federal buildings and suggests consideration of the frequency of vacuum occurrence in rating the hazards from disapproved plumbing.—*H. E. Hudson.* (*See also abstract* J. A. W. W. A. **30:** 719 (Apr. '38)).